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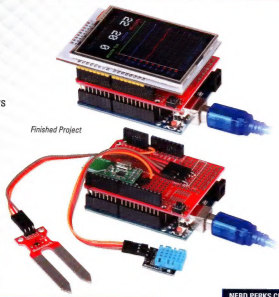
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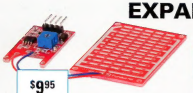
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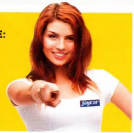

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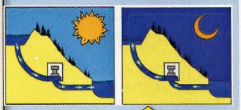

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Publisher's Letter

Pumped hydro storage is no panacea for renewables

Pumped storage will not allow renewable power sources to replace base-load power stations. There, I have said it. As indicated in last month's Publisher's Letter, we do have an article on Pumped Hydroelectric Storage in this month's issue, written by Dr David Maddison.

Australia has had the Snowy Hydroelectric Scheme for over 40 years and an important part of that system is pumped storage; Tumut 3, to be specific. Of course, the Snowy scheme was built long before renewable power sources were even thought of. It has been a great system and it could be expanded, as described in David Maddison's article.

However, when you want to substitute renewables for coal-fired power stations, which Australian state governments seem committed to, pumped storage won't allow renewables to give reliable 24-hour power delivery. If you wanted to substitute wind turbines for a 1GW coal-fired power station, say, you would need about 3000 1MW turbines, because they only generate power for about 30% of the time. If you are going to back up those wind turbines with pumped storage, you need a system similar in size to the Snowy's Tumut 3, which would only provide power for up to three days.

And if our national grid is to have a much higher proportion of renewable energy inputs instead of boring base-load power stations, then we have a much greater problem. The Australian Labor Party is advocating that renewable energy sources should make up 50% of the grid. That is just not workable.

Airbags could kill your daughter

Most people who read our feature article on Airbags in the November 2016 issue probably regard them as a wonderful development which reduces car accident deaths and serious injuries. Inevitably though, some people do manage to turn their car's airbags into potentially lethal weapons. How? Just consider all those young girls who ride in the front passenger's seat with their feet up on the dashboard; actually on the panel for the passenger's front airbag! I shudder to think of the severity of their injuries when the car has a collision in which that airbag is activated.

In just a matter of milliseconds, the passenger's airbag becomes fully inflated. At the same time, the girl's torso will have begun to "porpoise" underneath the seatbelt and her pelvis will keep moving at the car's original velocity into the foot-well, underneath the glovebox. At same time, her legs will be accelerated to more than 200km/h past her head, missing it, if she's lucky. Or perhaps not.

So what sort of injuries can she expect? The list probably includes smashed pelvis and damaged hips, broken legs, dislocated knees, all sorts of torn ligaments and tendons, and that's without considering severe internal organ damage, broken ribs, punctured lungs and the possibility that her knees and arms do collide with her face. Death seems highly likely just from shock.

Maybe you feel superior in not being guilty of the above stupidity. But many people sit way too close to the steering wheel – they are in harm's way. And if they drive with their right hand at 10 o'clock on the wheel (or with left hand at 2 o'clock), in the event of a collision their hand could become a projectile which hits their face at over 100km/h! So keep the wheel at arm's length and do not cross your arms over the wheel when driving.

I wish every reader a safe and happy New Year. Finally, last month we farewelled Greg Swain who has worked for SILICON CHIP since its inception in 1987 and before that, at Electronics Australia magazine; a period of more than 40 years. Enjoy your well-deserved retirement, Greg.

Leo Simpson

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Electric fence standard still specifies energy limits

I am writing to respond to the anonymous letter published on page 8 of the November 2016 issue, concerning the safety of electric fences. The writer suggested that the latest electric fence standards "no longer specify a limit on the energy delivered by a single pulse", and that energisers delivering 50 joules or more are now available, with the author implying that these are unsafe.

The electric fence standard AS/NZS 60335-2-76 includes comprehensive construction requirements that are updated regularly to keep up with the latest safety practices. The standard applies an RMS current limit and corresponding energy limit, at all loads. For the minimum likely load representing a human, this limit ensures that the shock delivered is safe.

Specifically, the RMS current value varies depending on the pulse duration. Longer durations require a lower permitted RMS current. This limit applies across the 500Ω component of the "standard load", where the standard load is defined as a 500Ω resistor in series or parallel with a variable resistor set to any value.

The 500Ω component represents the reasonably foreseeable "worst case" (least value) circuit resistance for a human coming into contact with an electric fence, taking into account serial impedances in the circuit formed.

The current limit is based on experimental work conducted many years ago and is on a similar basis to the limits that apply for RCDs. The limits are published in IEC TR 60479-2, "effects of current on human beings and livestock".

These limits are endorsed by the International Electrotechnical Commission (IEC) and have proven to be conservative over a long period.

Energisers with outputs over 5 joules are commonplace, however all those approved for sale in NZ and Australia comply with the output limits mentioned and are extremely safe.

Entanglement or entrapment is the main risk factor with electric fencing, and is the reason behind the development of the fence construction standard AS/NZS 3014 mentioned by the author. Overall the risks associated with electric fencing remain very small compared to other risks, such as being hit by lightning or driving a motorcar or farm bike.

Mark Harris,
Marketing Manager,
Gallagher Group Ltd.
www.gallagher.com

Mozzie Lure may not be total solution

Regarding the Mozzie Trap project in the October 2016 issue, well done on taking a lead to attempt to eradicate this deadly pest. Our evenings outside are invariably ruined at dusk by these pests, despite having tried all sorts of advertised devices. The potential health risks are apparently also increasing around certain cities in Australia.

I deduce that the daytime Aedes egypti is not the one that attacks at dusk, however. In the hope that the 484Hz tone generator device would be the solution, I read further via your link and found a comment by the James Cook researcher, Brian Johnson, who perhaps correctly comments:

"... there was no chance of eliminating mosquito populations by trapping males alone, as only a few needed to survive to continue the breeding cycle."

So, we may need a more comprehensive version with CO_2 generation, octenol, UV, fans and soapy water to provide a more effective lure. The CO_2 generator would need to emit around 3kg a week, normally generated from propane/butane!

Perhaps SILICON CHIP could liaise with Brian Johnson to see if we amateurs can help expand the attack on mossies. Their published data indicates that the 484Hz attractor would be an add-on to existing devices.

David Kitson,
Perth WA.

https://www.jcu.edu.au/news/releases/2016/january/love-hertz

Radio Australia's shortwave transmissions to cease

Radio Australia's transmitting station just north of Shepparton (Verney Road), the largest in Australia and perhaps the Southern Hemisphere, is to close on 31st January 2017. Radio Australia is an icon for both Shepparton and Australia, having been there since 1944.

To quote from the ABC press release: "The ABC will end its shortwave transmission service in the Northern Territory and to international audiences from 31 January 2017.

The move is in line with the national broadcaster's commitment to dispense with outdated technology and to expand is digital content offerings including DAB+ digital radio, online and mobile services, together with FM services for international audiences."

AND

"once international shortwave ceases transmission, international listeners can continue to access ABC international services via:

- a web stream at **www.radioaustralia.net.au/international/listen**
- in-country FM transmitters, see Radio Australia's 'Ways to Listen' at: **www.radioaustralia.net.au/international/radio/waystolisten/fiji**
- the Australia Plus expat app (available in both iOS and Android)
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Mailbag: continued

Does renewable energy really damage the Australian economy?

The argument that the recent "system black" outage in South Australia was caused by the use of renewable energy generation suggests that since wind-generation was in use prior to the system failure, the wind-generation MUST have been the cause of that failure – without any argument that would justify that conclusion.

Even the preliminary analysis now available from AEMO defines that the fundamental failure was a transmission failure caused by multiple structural failures of transmission towers in high winds. That transmission system failure bears no relationship to the generation sources involved – if a coal or gas plant was similarly isolated by a transmission failure, the network damage would be quite similar.

The Publisher continues to argue that intermittency of wind and solar generation necessitates expensive backup generation, which is a completely different topic appropriate to separate consideration. I note that the unique instance where extraordinary costs were involved for backup power in SA refers to a single short-lived incident where suppliers of gas-generated power shamelessly exploited a short-term shortfall.

I note that despite the forecast and a Severe Storm Warning (Destructive Wind/Rain/Hail) over significant areas, the Heywood connector was running at near full capacity (525 MW vs 600MW) which meant that it was vulnerable to overload and tripping in case of any significant faults on the SA side of the border. A loss of even 75MW would have caused trouble. The loss of access to 315MW of generation precipitated the shutdown of the connector and the resulting blackout that was then unavoidable. Had the interconnector been running at a lower level, the total system outage may have been ameliorated or perhaps even prevented.

The comparison to crises in other situations is quite facile. More details on the network topology and operational status at the critical times would be needed before any meaningful comparison is possible.

Jim Boyle, B.E. (Elec)
Hawthorn East, Vic.

Comment: you seem to overlook that 415MW from nine wind farms scattered right across the SA network shut down, yet all of the meagre, available, "real" generation soldiered on. It also appears that there was enough of the transmission remaining which would have enabled at least parts of the state to keep operating if there had been adequate base load power generation.

To me, this is a very short-sighted action that will deprive poorer people in the South Pacific and areas of Asia of a news and entertainment source. Many of these people don't have affordable internet access and shortwave radio is one of the few avenues they have for hearing world news.

In addition, shortwave radio does not recognise the boundaries of countries that do not welcome our shortwave services, so these people can hear outside news that is not censored by the ruling government.

The ABC does have local radio stations in various countries but these can be shut down very quickly by the administration of a country not wishing to have Australian news and entertainment available to their people.

If readers feel strongly about this I'd suggest they contact the ABC and various MPs and local councils, to express your opposition to this short-sighted action. Not long ago it was announced that Macquarie Island sub-Antarctic base was to close in March 2017.

Within around a week the negative feedback that the government got over this caused the relevant federal minister, the Honourable Josh Frydenberg MP, to reverse this decision and to effectively rebuild the base over the next decade. So readers' input could help reverse the decision to close Radio Australia.

To get a better range of information about this and the feelings of a number of groups go to: **about.abc.net.au/press-releases/shortwave-radio** and look at other internet sites which have further info which explains our concerns about this closure.

Rodney Champness,
Mooroopna, Vic.

Transistor symbols show current flow

I have to disagree with Greg Walker's letter (page 8, December 2016) as to why in this day and age we still use conventional current flow. When I went to radio tradesman school back in the early seventies they had switched to the so called politically correct electron flow.

I had great difficulty as did my class mates when we had to add up all the plus and minus voltages and convert them to currents when the signs were all incorrect for electron flow we often got it very wrong. It was a real headache on top of the work we were trying to do.

Things such as the transistor emitters' arrows showing conventional current whilst field effect transistors gates showed electron flow were also all very confusing. I was so delighted when years later in the mid-eighties I went back to school to learn about digital electronics to find they had changed back to conventional current flow.

It made our work around circuits so much easier. If they had just changed the plus and minus signs over instead of the arrows indicating current flow, all would have been good and everyone would have been happy.

I still have trouble today with working out what field effect transistor I am dealing with as in the diagram, the arrow for the gate is pointing the wrong way. The transistor emitter arrow points the right way.

David Francis,
Sydney, NSW.

Ionisation smoke alarms to be banned in Queensland

It has just been legislated in Queensland that ionisation smoke alarms will be banned from installation in new homes by next year, and from all homes in five years time.

I have read a lot of information online that seems to support the photoelectric alarms instead of ionisation alarms, as being the fastest to respond to the detection of smouldering smoke. However, I have not found any online testing results or any substantiated

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Mailbag: continued

Current flow is correct

The letter from Greg Walker, in the Mailbag pages of the December 2016 issue, perpetuates the myth that the current flow in metals is better explained by the direction that electrons move. This view is too simplistic. The Hall effect shows that, while in most metals the majority carriers are negatively charged (ie, electrons), in some metals, such as zinc, the majority carriers are positive.

The positive carriers are called holes and cannot be simply explained by electrons moving in the opposite direction as this would give the wrong sign to the Hall voltage. A fairly advanced understanding of solid state physics is required to explain this. Since the majority carriers in some metals are positive, there is no logically compelling reason to change the definition of conventional current which correctly indicates charge transfer whatever the carrier.

Nigel Miles,
Goosebery Hill, WA.

proof anywhere of this.

As a matter of fact, by my own personal testing, I have found results to be the reverse of any speculation. Anyone who has both ionisation and photoelectric smoke alarms installed in their homes can do simple tests to evaluate which of the two is the quickest to respond.

You can do this simply by using a mosquito coil or any other smoke source, and holding it at the same distance and angle away from each respective smoke alarm, keeping in mind that ventilation in the vicinity of both alarms should be as similar as possible.

By my own testing I have found that out of my 10 smoke alarms, all eight ionisation alarms respond in 40 seconds average time, and the two photoelectric alarms respond in six minutes average time. The tiny smoke from the mosquito coils can be compared to the VERY beginnings of smouldering smoke of a real house fire.

So the speed of response to the very initial beginnings of smoke is crucial, rather than waiting for thick toxic smouldering smoke builds up and the alarm responds, by then way too late!

So I turn to you, SILICON CHIP, the company that I've known for years and respect, is there something that I've missed, and can you accomplish any other tests more scientifically to determine which of the alarms are the best for quickest activation and response? This is a very crucial matter and may prove vital in saving peoples' lives.

As far as smoke alarms are concerned, I believe that many house fire tragedies are due to either having no smoke alarms installed, or installed alarms without a battery connected.

Interconnection of all alarms would help, with ionisation alarms installed in most areas that don't trigger false alarms, together with photoelectric alarms installed near the kitchen and garage. (I also have had a dual chamber ionisation alarm installed in the attic area from the beginning, with good response to testing and no problems there.)

The company which has pushed and lobbied for the demise of ionisation alarms (Louie Naumovski of Slacks Creek House Fire Support Services) is now aggressively pushing for legislation changes interstate and worldwide.

In one of his submissions on the Queensland Parliament website, he states that ionisation alarms are triggered by heat particles and not smoke from a toaster causing false alarms.

Heat particles - that sounds as new and mysterious as a black hole in the centre of the galaxy.

I placed my hand an inch above a smoking mosquito coil and could feel faint heat and by raising my hand another half inch I could feel no heat whatsoever, holding my hand there for some time.

By the way, the radioactive isotope Americium 241 used in ionisation smoke alarms is such a harmless non-soluble particle that its tiny alpha emissions only travel a few centimetres from it, and would be blocked by a sheet of paper, let alone the three enclosures of the standard alarm's plastic casings. Therefore, the combined dumping of these alarms in large quantities would keep each and every one of them still shrouding the particle within the layers of plastic.

Please reply on what your views are, and if you can't do your own tests please refer me to a reputable source, as the proper end results of smoke alarm efficiency may determine life or death for some.

Wally Fietkau,
Slacks Creek.

Comment: We do not have the expertise or resources to do the exhaustive tests which we assume would be required in order to decide to ban one type of smoke detector in favour of the other. It would seem that both types could be installed in households, as you suggest.

However, we are inclined to think that the real reason that ionisation types are to be banned is because they employ a radioactive isotope, Americium 241 and that would frighten uninformed people. Nor are we able to point you to any reputable source of information on this topic.

Publisher's letter unit confusion

On reading your Publisher's letter in the current issue of SILICON CHIP (November 2016), I noticed an error of omission in your mention of the cost of electricity. The unit of energy is a megawatt hour, not a megawatt.

I also tried to look at the Interesting Videos listed on page 23 but after trying to get the first three gave up as they were not available.

Alan Torrens,
Hornsby, NSW.

Editor's note: we checked the YouTube links on pages 22 and 23 of the November 2016 issue (there are two on each page) and they all loaded fine. Please make sure you aren't omitting the full stop between the "youtu" and "be".

50A charger regulator's connections can be improved

I would like to comment on the 50A battery charger regulator described in the November 2016 issue, as I disagree with your construction method.

How the high amperage cables are connected, is in my opinion, incorrect. Firstly, you have specified steel or

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I have been in the security business for over 38 years now. I have used a lot of soldering irons over the years from electric irons with tangled extension leads to gas soldering irons that run out of gas halfway through the job.

I now own two Aussie Rechargeable Irons – the best soldering irons by far that I have ever used. When I saw the prototype I had to have one.

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Mailbag: continued

South Australia's electricity grid is inadequate

I have just finished reading the November Issue Publisher's Letter. I have to disagree with you using the September South Australian blackout as an argument against renewable energy. I am not a "greenie" per se but I see a future with renewable, some non-renewable, and even (dare I say) nuclear energy. Your argument that wind generators caused the state wide blackout is incorrect.

Firstly, the high winds started in the morning and continued unabated all day and through the night. So if the wind had caused the turbines to shut down, they would have been shut down for most of the day. There were localised blackouts due to the wild weather.

According to one report the state wide blackout started at 3:50PM, but we still had power in Adelaide southern metro until around 5:20PM.

You only mention in passing that some "spindly" transmission towers were knocked down. Are the other state's towers different from South Australia's? In fact, it was 23 transmission towers that blew down, some of which were 275kV line towers. After the third 275kV line shorted, some of the wind farms reduced their output, and then the Heywood interconnector tripped. That was within seconds.

After that the non-renewable power stations went down along with the remaining wind farms and the Murray interconnector. If the interconnectors did not disconnect, Victoria's grid would probably have gone down as well.

The wind farms did not cause the blackout, it was the downing of three 275kV transmission lines by unprecedented weather conditions that caused the entire South Australian grid to overload and shut down. The blackout would have happened with or without the wind farms. This has been agreed by industry experts. Oh, the wind farms were producing power until the grid shut down.

The truth is that South Australia's electricity grid is inadequate and has been for decades. But even a perfect grid can not anticipate or cope with every possible disaster scenario.

As for your examples of other severe weather outcomes, did those events happen across an entire state and hit most of the infrastructure? Cyclones in Queensland only affect a small part of the landmass and the affected areas are automatically disconnected to protect the rest of the state.

As for poor Haiti, there wouldn't be much left of anything, let alone a power grid. In Florida, 2.2 million homes and businesses blacked out, that's very much more than the whole of South Australia which has only 1.7 million people.

I do not know why you insist on bashing renewable energy every chance you get. I agree with some parts of your arguments, such as base load power. As an engineer I know that what is not viable today, may become viable tomorrow. Science and engineering march forward every day and new solutions are found to many problems. So I would encourage research into better, cleaner energy generation, not discourage it.

Tony Onofrio,
Highgate, SA.

stainless steel bolts. The bolts should be brass, in line with common practice for high amperage fittings.

Secondly, the method of bolting the cables together and to the case is the biggest concern. In time, this arrangement is likely to overheat and/or come loose.

The correct method of connecting the cables is as follows. Firstly, take a bolt and place one of the lugs over it. Then thread on a nut and tighten the nut securely. Next, push this assembly through the hole in the ABS box and thread on another nut and secure it firmly.

Then place the other lug on the bolt and thread on another nut, which is tightened securely. The bolt head may be either inside or outside, but it's preferable to have it on the inside, to enable easy removal of the external cables if required.

This method ensures that each lug is held tightly between two nuts or a nut and the bolt head. It may not be as cosmetically appealing as the method shown in the article, but it guarantees a much higher reliability, with negligible chance of the connections becoming loose or overheating.

Bruce Pierson,
Dundathu, Qld.

The AEMO has questions to answer about SA blackouts

Leo Simpson's explanation of the events that initiated the state-wide blackout in South Australia on the 28th of September this year (Publisher's Letter, November 2016) is inconsistent with the reports published by the Australian Energy Market Operator (AEMO). These can be viewed on the AEMO website at www.aemo.com.au

The event was initiated by a narrow storm cell with hurricane force winds that travelled across the mid north of the state from the west. It left a narrow band of destruction in its path that crossed three separate 275kV transmission lines. All three transmission lines suffered a catastrophic failure of multiple towers.

Let's be clear about this! The wind turbines in the area only started to automatically shut down after their safety systems detected voltage disturbances caused by the destroyed towers and not because of the high winds. According to the Bureau of Meteorology, this was a once in 30-year event which had far more destructive power than a 'stiff gale'!

On an unrelated matter, your editorial rightly stated that the cost of peak power in South Australia "has risen as high as $14000 per megawatt" (note that "megawatt' should have been "megawatt hour").

This occurred in early July 2016 when high winds caused most of the wind turbines functioning at the time to shut down. There is no doubt that the high proportion of wind power installed in South Australia was a factor in this crisis. However, this may be blaming the molehill instead of

looking for the mountain.

The interconnected electricity grid across all Australian states except Western Australia and the Northern Territory is managed from control centres in Brisbane and Sydney by AEMO. Generators throughout the network are told when to go on or off line by one of these centres after a so-called free market bidding process.

AEMO certainly would have known that the Heywood connector link was down for an upgrade at the time and that there were unfavourable wind forecasts from the Bureau of Meteorology.

Therefore, why did they leave idle over 1600 megawatts of baseline gas fired generation capacity which was available in Adelaide at the time? We can only speculate that coal-fired power generated in the Latrobe Valley was more profitable for the generator owners than gas-fired power from Adelaide, and that the high wind forecast was possibly ignored.

In other words, the way AEMO currently functions is the main reason why the electricity spot price went unrealistically high. Perhaps the enquiries currently in progress will bring about change.

Stan Woithe,
Fulham Gardens, SA.

Radio, TV & Hobbies DVD enjoyed

A couple of years ago I received as a Christmas gift a copy of the Radio, television and Hobbies: The complete archive on DVD. My thanks to the folks who put so much effort into scanning this history of technology. I quickly located the first valve and transistor radios that I built back in the 1950s and 60s and re-lived the excitement of first listening in to shortwave broadcasts from around the world.

It is hard to believe today that 60 years ago, people rejoiced at the possibility of owning a portable radio the size of a shoe box, the weight of a brick, with an output power of less than 100mW and all this while consuming expensive batteries at an alarming rate.

Early issues featured articles on building items as basic (and challenging) as electric gramophone motors etc, as well as wood-working plans to make toys and cases for radios.

In March 1947, we were told that "Astronomers are definite that there is some form of seasonal vegetation on Mars". Another immediate post-war issue featured an article suggesting that future passenger aeroplanes might have each passenger in a separate capsule fitted with a parachute to lessen the risk of air travel!

Even more interesting was reading the opinions about the future of what we have come to call "electronics". For example, in March 1951, an expert "doubted if even the BBC with all its resources could manage even one high grade television program without outside help." (Some would say he was right!)

In March 1954, a report told us that TV had been successfully recorded on magnetic tape at 30 feet per second!

In February 1955, it was predicted that flat-screen TV with no picture tubes would be available within five years! We got there eventually but not until around 50 years later!

In April 1957, the radio trade was trying to sell the 17-inch screen as the ideal size for Australia.

In April 1963, the respected editor Neville Williams conveyed the views of most people of the day when he ridiculed the prediction that as greater bandwidth became available, eventually even children would have their own mobile phones to chat with their friends. As Mr. Williams said, "Let's be realistic!"

It all makes me wonder how far off the mark present-day predictors of the future might be! As for the wartime propaganda, well, it certainly is interesting to read. Thank you for an enjoyable nostalgia trip.

Graham Lill,
Lindisfarne, Tas.

Nuclear submarines to be preferred

I spent 15 years in the Navy as a helicopter pilot specialising in anti-submarine warfare, so it was of great interest to read the article on nuclear submarines in the December 2016 issue.

Back in the 1970s nuclear submarines were noisy (especially if they put on speed) but our 'Oberon" class boats were the devil to find. I have never worked against a Collins or a modern nuclear sub but I imagine nearly 40 years of improvement makes them a formidable system, so I hope the

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Navy's new 'Romeo' class ASW helicopters will be up to the task.

I agree with the assessment in the Publisher's Letter in the December 2016 issue and think the Navy should take the "steam-kettle" option, or man/jointly-man an American boat with the future looking to operate one or more ourselves.

John Vance,
Bibra Lake, WA.

How to dim overly bright LED displays

I thought I would write in and pass on this useful tip. Recently, I needed to dim a panel-mounting digital thermometer LED display that I use to monitor the temperature within my audio rack and it was not possible to do this electronically.

I used my inkjet printer to print a very dark grey rectangular shape (40 x 20mm) with 5% transparency using Word (shapes) on an overhead transparency sheet. I cut this out and inserted it between the LED display and the existing front diffuser. The result was perfect, with the colour (blue) unaffected but brightness dramatically reduced. Obviously, the brightness can be adjusted by changing the Fill transparency in Word.

Malcolm Fowler,
Mt Eliza, Vic.

Typical caravan refrigerator wiring is inadequate

In November 2016 issue I read with interest on page 44 about a problem with a refrigerator in a caravan. A number of years ago my wife and I purchased a caravan. The refrigerator didn't appear to work on 12V supplied from the vehicle whilst travelling. I checked the voltage at the drawbar and it was 12V which is satisfactory, just, but when I checked at the refrigerator it was only 8V.

I found no problem with the wiring except that it was too light. The cable was rated to carry the necessary current to the refrigerator but the wiring of that caravan and most others simply has too much voltage drop.

I replaced the light-duty 12V cables with heavy cables rated at over 50A (in fact, I used two 50A cables in parallel) and installed 50A Anderson power connectors at the drawbar and the vehicle. The vehicle also had heavier cable installed from the battery to the drawbar. The metal chassis was used as the negative "lead" from the drawbar to the refrigerator.

Some say this is unreliable in both caravans and vehicles, however, when done properly it is very satisfactory, with minimal voltage drop. The refrigerator then worked. A few years later we purchased another caravan and as with the first one, the wiring was too light so it was immediately upgraded; all was well.

Later on we changed the tow vehicle and then we found out after travelling for about an hour on our first trip that the caravan battery, refrigerator and rear view camera were receiving only about 11.5V. So the refrigerator was draining the battery and not working properly; not what I wanted.

I then thought that the alternator had developed a fault as its output was only 12.6V. Checking with the dealership it was established that the vehicle had a smart alternator, which most new vehicles have. These alternators drop their output voltage after a period of time when the battery is deemed to be charged.

As a result of this I had to fit a DC/DC converter to make sure that the battery and refrigerator in the caravan received something like 13.8V. These inverters will work with voltages between around 8 and 16V and give a regulated output voltage of around 13.8V.

The combined charge current to the battery plus the refrigerator drain of around 14A totalled around 25A from the converter. However, the current drain from the vehicle is greater than this as there is a step-up in voltage required plus the efficiency of the converter needs to be considered. The drain from the vehicle is now around 35A. If light cables were still used in the caravan, this current would be even higher.

Caravan refrigerators when run on 12V have no thermostat in operation, but they do on AC and gas. I suggest the reason for this is that the refrigerators rarely receive 12V and therefore rarely work properly anyway.

I did an experiment and applied voltages from 14V down to 11V to the refrigerator. At 14V it worked very well but below 12V, it did not function at all. So light-duty cables and 3-way refrigerators are not a good mix.

On a separate topic, I have had the same concerns as expressed about electric fences, as on page 8 of the November 2016 issue, for many years.

Rodney Champness,
Mooroopna, Vic.

Wind turbines should not be discredited

Your Publisher's Letters in both the November and December 2016 issues SILICON CHIP put the blame on the SA blackout on 28th September 2016 on renewable energy, specifically wind turbines. Furthermore, headlines in most Australian newspapers at the time, and some of your Mailbag correspondents have also laid the blame on these devices.

This tends to discredit wind turbines as a valuable source of renewable energy, particularly to the general public who don't quite grasp their inherent advantages, and to the NIMBY's and infra-sound objectors in the community.

Wind turbines, per se, are not at the root of the problems which led to the SA blackout, but rather it is their rapid introduction into our national electricity grid without due consideration of overall system stability, quantified by such parameters as RoCoF (rate of change of frequency) of the grid's alternating current.

The AEMO Incident Reports of the 5th and 19th October 2016 reveal that six voltage disturbances, triggered by the storm and collapse of transmission towers led to 445MW of wind power being disconnected (not as you reported, because the turbine blades were feathered to stop self-destruction).

Furthermore, the Farrier Brier paper – ref Paul Miskelly's letter, SILICON CHIP December 2016 – reveals that the ability of wind turbines to ride through system voltage disturbances is a complex issue, but which can be addressed by software adjustments and other mechanical improvements so that some of the turbines' mechanical inertia can be harnessed to provide synchronous inertia. Such work is

Technical changes do cause loss of jobs

In the Publisher's Letter for the November 2016 issue, you say that changing to renewables for the production of electricity has required expensive backup generation and higher costs to consumers. The general tone suggests that the move to renewables has been disastrous, expensive and has caused loss of jobs.

65 years ago, my teacher told us we had 600 years worth of coal. This is now 200 years worth and falling. Oil will run out before the end of the century. Uranium sources are rapidly depleting. We are still fiddling with Thorium. Nuclear fusion is still 30 years down the track, as it has been for the last 60 years.

Changes have frequently caused loss of jobs; weavers, sailors, navvies, typists, warehousemen, lawyers, teachers, to name a few. New jobs have appeared.

You have stated a problem. What is the solution? Reverting to fossil fuels, moving to nuclear, decentralising generation, using a mix, or what?

Peter Hadgraft,
Brisbane, Qld.

Comment: Whatever was known about Australia's mineral reserves 65 years ago was completely wrong. After all, there was then an embargo on iron ore exports because we thought we had limited supplies but then the Pilbara was discovered. We have truly vast reserves of uranium and we are using it at a very slow rate. And after all the false warnings about "peak oil", there are now known to be huge reserves of oil and gas around the world.

The trend to renewables is extremely expensive, although solar panels are becoming a lot cheaper. Many thousands of jobs have been lost in Australia because of the rising cost of energy and this trend will continue unless there is a major change of heart by State and Federal governments.

Promoting parasitic power producers

Wind and solar are parasitic power producers, unable to survive in a modern electricity grid without the back-up of stand-alone electricity generators such as hydro, coal or gas-fired or nuclear. And like all parasites, they weaken their hosts, causing increased operating and transmission costs and reduced profits for all participants in the grid.

Without subsidies, few large wind/solar plants would ever be built and without mandated targets, few would get connected to the grid.

Green zealots posing as energy engineers should be free to play with their green energy toys at their own expense, on their own properties but the rest of us should not be saddled with their costs and unreliability.

We should stop promoting parasitic power producers. As a first step, all green energy subsidies and targets should be abolished.

Viv Forbes,
Rosevale, Qld.

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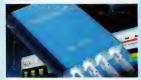

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Mailbag: continued

High current mains wire termination

Dave Thompson's comments regarding his pole fuse problems in November's "Serviceman's Log" brings back all sorts of memories from my youth on the Eastern side of the ditch.

In those near prehistoric days, the Supply Authority was a County Council, which was a semi-government Authority responsible for supplying power and associated services in a given geographical region.

Granted, some "feather-bedding" happened in these organisations but all profits were ploughed back into capital works projects. Local street power transformers were upgraded, feed cabling was replaced with cabling of higher current carrying capacity, new switch/transformer yards were built and so on.

This benefited the consumer, kept power pricing low and actually worked!

The fault that Dave described and the final outcome was/is caused by placing stranded cabling in a terminal tunnel with a somewhat larger diameter than the cable diameter, without taking suitable precautions.

As the grub screw-securing the cable is tightened the cable will spread at right angles to the force applied by the screw. This results in some strands not bonding completely with the terminal.

The effective cross sectional area of the cable is reduced, likewise the current carrying capacity of the bonded part of the cable. The strands that are not completely bonded as they pass current generate heat and it is only a matter of time until the connection fails, often with quite spectacular results.

This problem can be prevented by two similar methods prior to inserting the stranded cable and tightening the terminal screw, either by fitting a crimped ferrule to the cable to prevent the cable from spreading, or wrapping 20A fuse wire around the stranded cable for the full length of the stripped section.

This was known as "binding wire" and was the technique used by the County Council Officers when they installed the mains supply protective fuses and consumer metering on clients' premises.

In recent years, I found myself working as an electrician again in a food production plant. The policy at this organisation was that all terminated cabling, no matter how small the current, had to have a ferrule fitted.

Any electrician caught not complying with this policy would spend a rather interesting half hour in the engineering manager's office, with the electrical supervisor in attendance and with the door shut!

Lyndon Dyer,
Dean Park, NSW.

already underway in Quebec, Canada.

After the event, many detractors of wind turbines are scurrying about to discredit them, and AEMO and the SA government are trying to paper over poor decisions of their own making.

However, it does appear that the root cause of the blackout relates to insufficient synchronous inertia – which is normally provided via the rotating mass of synchronous generators – being available to allow the SA system to ride through the unprecedented disturbances.

The currently installed wind turbines have little or no synchronous inertia, and about 1GW of conventional synchronous generation capacity had been taken off-line for reasons unrelated to the storm, and before it struck.

Nobody seems to have picked up on the fact that system stability can be improved though planning and application of available technology. For example, additional suggestions made by Farrier and Brier include:

1) Installation of new synchronous condensers (synchronous generators with their excitation current controlled so that the generators appear to the grid as a condenser/capacitor, and a source of synchronous inertia). Such devices need very little fuel to spin them at synchronous speed, and retired generators in aging fossil fuelled power stations could be converted at reasonable cost.

2) Installation of high-speed load shedding equipment as a capitally cheap but operationally expensive option to simulate the addition of synchronous inertia.

3) Incorporation of distributed battery storage, of the type being installed by consumers to absorb surplus solar energy, to inject energy into the grid under emergency conditions, again simulating increased synchronous inertia.

The Federal Government's negative attitude towards renewable energy and nuclear power are well known but failing to plan is planning to fail. These alternative technologies must be discussed in a sensible, non-emotional, pragmatic way, and incorporated gradually to minimise the impact of change.

We all want to reduce our CO_2 emissions, and the way forward is to acknowledge that, whilst compromises must be made, we cannot just ignore the hazards of fossil fuelled generation.

Nor the opportunities of thorium and other nuclear fuel cycles, solar and wind, to produce a balanced mix of systems which will serve our nation and the world well into the future.

One could even reflect on the irony that the ferocity of the storm that precipitated the SA blackout was brought about by anthropogenic climate change!

Rob Fincher,
McCrae, Vic.

Comment: no climate scientist has stated that the South Australian blackout was "brought about by anthropogenic climate change". That weather event may have been severe but overall, severe weather events have reduced in intensity over the last 30 years.

Moreover, not all people are convinced that our CO_2 emissions should be reduced or even that it is leading to any significant degree of global warming. And even if that were the case, there are significant benefits of a slightly warmed climate in most temperate countries. SC

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One of the problems associated with renewable energy sources is that they are intermittent – they stop producing power when the Sun goes down or the wind stops blowing. Proponents of renewables see pumped hydroelectric storage and batteries as being the solution. Are they the answer?

PUMPED HYDROELECTRIC STORAGE

by Dr David Maddison

Tumut 3 image by Colin Henein

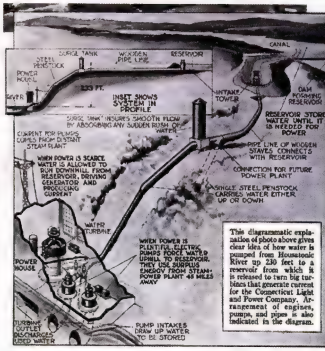
Pumped hydroelectric storage is a method of storing or releasing large amounts of electrical energy to or from a nation's electricity grid.

Typically, it uses surplus electricity to pump water to a higher elevation and then later releases it through a hydroelectric generator back when it is needed. The gravitational potential energy of the water is the stored energy.

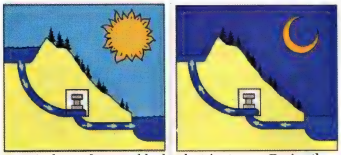
Pumped storage was used as early as the 1890s in Austria, Italy and Switzerland for better management of water resources but not initially for storage of electrical energy. In the 1930s reversible hydroelectric turbines became available and the first pumped hydroelectric storage scheme was built near New Milford, Connecticut, USA in 1930, although in that case separate pumps were used rather than reversible turbines.

Compared to other large scale electrical energy storage schemes, pumped hydroelectric storage is relatively cheap, requires little maintenance and with the right geography, can be implemented on a massive scale. It has the disadvantage of relatively low energy density, so a huge volume of water raised to a suitably high elevation needs to be utilised. The low energy density is the consequence of gravity being the weakest of all the natural fundamental forces.

Grid-scale energy storage has traditionally been used for "load balancing". This enables a power station to run at peak efficiency even though it means that at certain times it will be generating too much power. Rather than reducing the output of the power station, which could result in a loss of efficiency, its excess energy is stored. So the output



The world's first pumped hydroelectric storage power plant in Connecticut, USA, reproduced from Popular Science magazine, July 1930. Note how the pipeline consists of wooden staves in part, a common technology of the time and which was also used in parts of Victoria's Rubicon Hydroelectric Scheme (see SILICON CHIP, February 2013).



A typical use of pumped hydroelectric storage. During the daytime, water flows downhill through turbines, producing electricity. At night, water is pumped back up to the reservoir using excess electricity, ready for tomorrow's use.

of the power station remains relatively constant against a varying electrical demand.

It also means that electrical demands that exceed the total power of the generators can be met, for as long as there is stored water to discharge. This enables a smaller power station to be built than would otherwise be needed to satisfy peak demand.

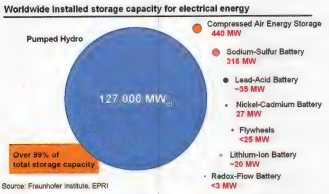
A typical application would be to store surplus energy at night (when demand is lowest) and release it when demand is highest during the day.

Today, it is government policy to have a high and increasing amount of intermittent energy sources such as solar and wind generators to supply the grid. This causes very difficult grid management problems and instability issues. Pumped storage is one way to smooth over the constantly varying outputs of these intermittent energy sources in order to stabilise it.

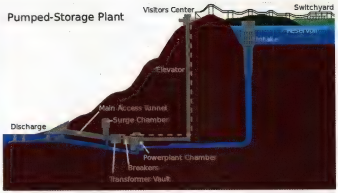
Even better, wind and/or solar generators could be used to directly supply power to pump water into a reservoir and thereby have no direct electrical connection to the grid. This approach will be used in some places such as the Espejo de Tarapacá project in Chile which will use solar power to run its pumps.

Note that pumped hydroelectric storage is suitable to stabilise only relatively small amounts of intermittent energy and would not be suitable for backing up an entire grid which had substantial inputs in the form of intermittent energy. Huge amounts of storage would be required to do this.

In most countries, the lack of suitable sites, the large cost



Approximate proportion of grid-scale energy storage around the world. These are the latest available figures (2011) but current estimates suggest over 140,000MW of pumped hydro storage. These figures only specify the deliverable power, not the total time that power could be delivered. Note also that over 99% of grid scale storage is pumped hydro.



A typical pumped storage hydro plant. This one happens to be the Raccoon Mountain Pumped-Storage Plant in Tennessee, USA but its features are typical. This one has a natural lake as its lower reservoir, an artificial upper reservoir and it can produce over 1.6GW of power for 22 hours. The upper reservoir takes 28 hours to fill.

and the environmental damage of such facilities would make them impractical.

Unfortunately traditional forms of pumped storage generators and pump units are not especially well suited to smooth the rapidly varying outputs of solar and wind generators. However, new variable speed pump-generator units are available that are more suited to this application.

Alternatives to pumped storage

The worldwide installed capacity for grid-scale storage is overwhelmingly pumped hydroelectric storage, being over 99% of installed capacity. However, there are a number of other options for grid scale electrical storage and these include battery banks, large flywheels, or compressed/liquefied air.

Rechargeable batteries can be used to store energy but they are expensive and tend to degrade over time.

Flywheels can store energy by being spun up by a motor generator set and then when energy is needed, the generator is used to produced electricity. But flywheels tend to be uneconomic in the sizes required for large scale energy storage.

The King Island Hybrid Power Station in Tasmania is an interesting example of a power station that uses several power generation and storage technologies. It comprises a 2.45MW wind farm (nameplate, with a capacity factor of around 29% so the effective output is 710kW), a 100kW solar array and a 6MW diesel generator plant working with a backup battery and a flywheel.

It originally used a vanadium redox flow battery which had a storage capacity of 800kWh and an output power of 200kW. However, the system was not robust and was replaced with a lead-acid battery with a capacity of 1.6MWh and a power delivery of 3MW.

Another part of the system is a flywheel. This does not store a large amount of energy but is used as part of a "diesel rotary uninterruptible power supply (DRUPS)" whereby a flywheel is kept spinning as an energy reserve and when supply falls it drives a generator to supply power. If after some period of seconds supply does not increase, a diesel generator is started to make up the demand.

The whole King Island system requires a $7 million dollar per year subsidy from the Tasmanian Government ($2,500 per person). You can see a real time schematic of

the system in operation, including power flows at www.kingislandrenewableenergy.com.au/

Compressed air energy storage typically utilises an old mine or geological structure such as an excavated salt cavern or depleted gas well to store compressed air at times of excess or cheap energy and then it is released through a turbine to generate electricity at times of peak demand.

One company is developing bags of compressed air that are stored underwater. See http://hydrostor.ca/home/

Compressed air storage can also be used in conjunction with a natural gas turbine to improve its efficiency. A variation of compressed air storage is to liquefy the air and allow it to expand back to its gaseous state to generate electricity via a turbine.

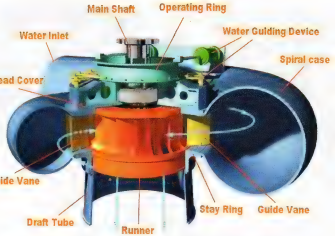
Hydroelectric turbines

Only certain types of hydroelectric turbines are suitable for pumped storage if a single unit is required rather than utilising separate pumps to send the water back up to its reservoir.

The type of turbine used in any particular application is determined by the water head and flow rate available. The three most common types are the **Pelton wheel** which is best for a large water head and low flow rate (for more on the Pelton wheel see SILICON CHIP "The Historic Rubicon Hydroelectric Scheme" February 2013, page 18); the **Kaplan turbine** which is best for low water head and high flow rate; and the widely-used **Francis turbine** which is good for a great variety of conditions, mainly medium head and medium flow rate applications.

Unlike the Pelton wheel and the Kaplan turbine, the Francis turbine can also be used as a pump, making it ideal for use in pumped storage schemes. About sixty percent of the installed hydroelectric capacity in the world uses the Francis turbine.

The Francis turbine can spin up quickly so changing power requirements can be quickly accommodated and it is available in a wide range of power capacities from a few kilowatts to 800 megawatts. The turbine consists of three main parts: the spiral casing, the guide vanes and the runner blades (or runner). In turbine mode, the spiral case distributes water around the periphery of the turbine inlet, after which it passes over the adjustable guide vanes, which direct the flow onto the runner blades at the required angle for the present flow rate. The runner blades cause the tangential flow of water to be converted into rotational motion of the main shaft which turns an alternator.



Francis turbine, which can also function as a pump to reverse water flow. (Image courtesy Eternoo Machinery Co.)

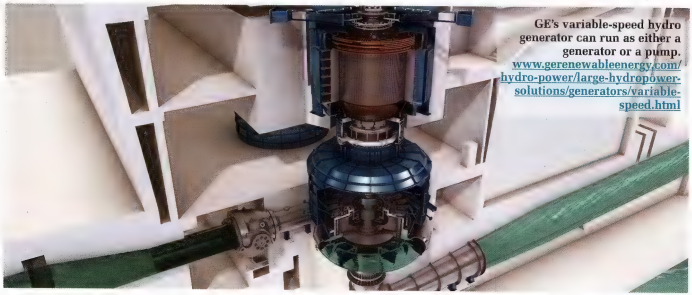
Variable speed hydroelectric generators

Motor-generator equipment connected to a Francis turbine as used in hydroelectric storage schemes has traditionally only been able to be operated at a single speed and power rating. For example, if a plant had three 100MW generator units to be used for pumping water and there was 270MW of surplus energy to be utilised for pumping, only the first two units could be used to absorb 200MW of this surplus energy. The third 100MW unit could not be used as it would require 100MW to operate and only 70MW would be available so the 70MW would have go to waste.

By contrast, a set of three variable-speed motor-generator units could adjust their speed to utilise all available energy for pumping and could each operate at 90MW.

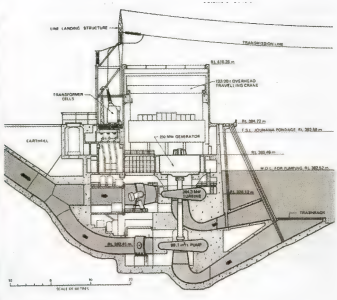
In addition, when operating in generator mode a variable speed unit can be adjusted for optimal efficiency of operation when only a partial load is being drawn.

In a single speed motor-generator set the stator's magnetic field and the rotor's magnetic field are said to be coupled as they both rotate at the same speed. In a variable speed



GE's variable-speed hydro generator can run as either a generator or a pump. www.gerenewableenergy.com/hydro-power/large-hydropower-solutions/generators/variable-speed.html

Aerial view of Tumut 3 Power Station. The red area contains the penstock (pipes) and power house. The orange area is the Talbingo Dam Reservoir, the upper storage of the scheme. You can explore this in more detail with the ability to zoom in and out at http://globalenergyobservatory.org/form.php?pid=45928



Cross-section of turbine and pump arrangement at Tumut 3 power station. There are six generators which originally had a capacity of 250MW each but these were all upgraded to 300MW in 2009-11. Three of the generators have underslung pumps to pump water uphill for storage.

unit these two magnetic fields are decoupled and either the stator or rotor magnetic field are fed via a frequency converter. A "double-fed induction motor-generator" (also known as a double-fed induction machine, DFIM) is the current standard design for variable speed motor-generators.

It may be feasible and economical in some circumstances to convert an older fixed-speed storage plant to a variable speed one. See **www.hydroworld.com/articles/print/volume-21/issue-5/articles/pumped-storage/converting-to-variable-speed-at-a-pumped-storage-plant.html**

Video: *"How does GE's Hydro Variable Speed Pumped Storage technology work?"* **https://youtu.be/CdlvjkfpX_o**, *"GE Hydro Pumped Storage"* **https://youtu.be/2qZxfnMDrco**

Australian pumped storage projects

Australia has three working pumped hydroelectric projects in operation and one in the planning stage. **Tumut 3** in the Snowy Mountains has the greatest power generating capacity with up to 1800MW output, followed by **Wivenhoe** in Queensland with 500MW and the **Shoalhaven** scheme in NSW with 250MW maximum output.

The Tumut 3 power station of the Snowy Mountains Hydro-electric Scheme was Australia's first pumped hydroelectric storage scheme, completed in 1973. In 2003 six micro-hydro generators, each of which has a power output of 140kW, were added to the outlets of the six generator cooling systems, which recovered otherwise wasted energy.

Then in 2009-11 Tumut was upgraded with new turbine runners and other improvements to each of its six generators, increasing its overall power output from 1500MW to its present capacity of 1800MW (1.8GW), under ideal conditions.

Even though the Francis turbines used at Tumut 3 could theoretically be used for pumping (as at other pumped storage facilities), in this case there are separate under-slung pump units for pumping water.

Tumut 3 pumps water between its lower reservoir at Jounama Pondage and Talbingo Reservoir as its upper storage. The water head is approximately 155 metres.

Snowy Hydro has not published the electrical storage capacity of Tumut 3 or the way it is used in typical operation but we estimate it as follows: there is approximately 160 gigalitres of active water storage. The six turbines (before the upgrade) had a total discharge capacity of 1,133,000 litres per second. This implies that it would take around 39 hours to discharge all active water storage at maximum power. Hence, there is about 70.2GWh of electrical storage.

In energy storage mode, the three pumps each have a

Pumped storage calculations

In calculating the power that can be generated by any hydroelectric project the two main numerical considerations are the water flow that can be directed into the turbine/alternator and the head of the water.

These items scale linearly so doubling of either the flow or head will result in doubling of the power that can be produced.

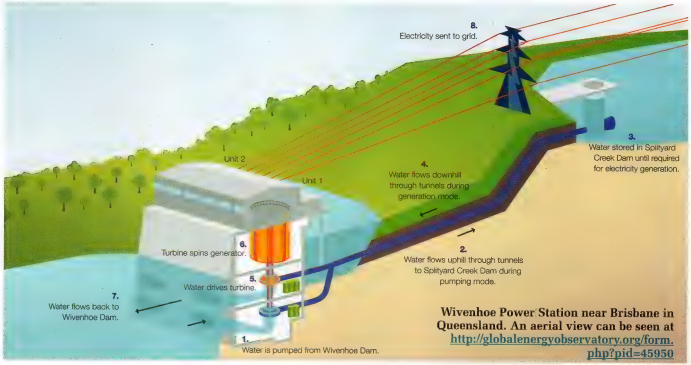
The power produced is given by the equation:

power** (watts) = **head** (metres) x **flow** (litres per second) x **gravity** (9.8 metres per second squared) x **efficiency factor

Let's do a real-world calculation for the Tumut 3 power station discussed above. We will consider the power produced from discharging the water and disregard losses from initially pumping it into the upper reservoir. It has a head height of 155m and a flow rate of 1,133,000 litres per second (prior to the upgrade).

Without considering the efficiency factor, this yields 1721MW of power generation. Note that before the upgrade it had a quoted power output of 1500MW so this implies an efficiency of 87%.

When doing calculations for pumped schemes consider that there is an efficiency loss in both directions.



Wivenhoe Power Station near Brisbane in Queensland. An aerial view can be seen at http://globalenergyobservatory.org/form.php?pid=45950

capacity of 99,000 litres per second (297,000 litres per second total) so the Talbingo Reservoir would take 448 hours to refill, assuming the lower reservoir could store all the water that was discharged. Of course, the storage is unlikely to be fully discharged in normal operation.

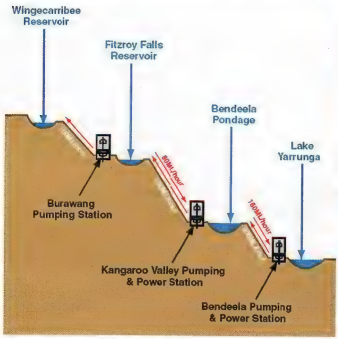
Wivenhoe Power Station, located near Brisbane, is a 500MW pumped hydroelectric scheme which utilises a lower reservoir created by the Wivenhoe Dam and an upper reservoir created by the Splityard Creek Dam. The lower reservoir is approximately 100m below the upper one and is connected by two pipelines 420m long and between 6.8m and 8.5m in diameter.

The power station has two 250MW pump-generator machines, said to be Australia's largest hydroelectric machines, each having a rotating mass of 1450 tonnes. There is 5000MWh of capacity so, for example, 500MW could be produced for 10 hours. The station is connected to the grid via 275kV transmission lines.

Like all hydroelectric schemes Wivenhoe has an exceptionally long expected service life – 100 years – and has been in service since 1984. A generator was added to the outlet of the Wivenhoe Dam in 2003 to provide 4.5MW and this is known as the Wivenhoe Small Hydro. It is not directly associated with the pumped storage scheme.

(You may recall that the Wivenhoe Dam was associated with the Brisbane floods of 2011 and subsequent enquiry).

The Shoalhaven Scheme is located on the South Coast hinterland of NSW and is used for water supply and up to 240MW of hydroelectric storage power. It has two combined power stations and pumping stations. The lowest one is



The diagram at left shows the Shoalhaven Scheme, which is a combined pumped hydroelectric system and a water transfer system to supply drinking water to Sydney, about 150km away. The Kangaroo Valley Pumping and Power Station (above) is the middle of three such stations.

The proposed Kidston Hydro Project will use two existing unused mining pits plus a "turkey's nest" reservoir.

the Bendeela Power Station and has two 40MW combined pump-turbines to provide 80MW. In pump mode it can pump water to the Bendeela Pondage located 127 metres above.

The Bendeela pondage is located below the Kangaroo Valley Power Station (1977) and has two 80MW power stations for a total capacity of 160MW. When operating in pumping mode it can pump water 480 metres up to the Fitzroy Falls Reservoir.

The Burawang pumping station is not used for pumped storage but to pump water into the Wingecarribee Reservoir from where it can be released into the Warragamba or Nepean Dams. The scheme can produce 240MW of power.

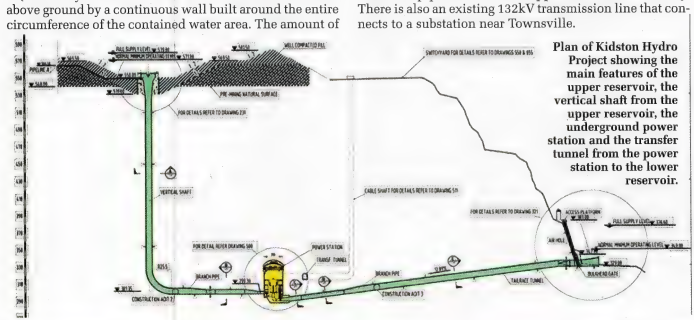
The proposed Kidston Hydro Project (about 1300km northwest of Brisbane, Qld) will utilise two mining pits which were formerly part of the now-closed Kidston Gold Mine. In addition, a "turkey's nest" reservoir will be constructed to provide two storage reservoirs (an upper and lower) and a "balance reservoir" to effect a pumped storage scheme using mostly existing artificial structures.

(A "turkey's nest" reservoir or dam is one constructed above ground by a continuous wall built around the entire circumference of the contained water area. The amount of earthworks required for a turkey's nest type of reservoir is typically considerably greater than damming a natural structure such as a valley.)

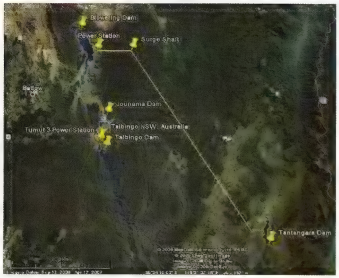
There would be a vertical shaft from the upper reservoir and an underground generator station, with the outflow connected to the lower reservoir.

According to a feasibility study by Genex Power, the proposer of this scheme, it would be able to continuously produce 250MW of electricity for six hours giving a storage capacity of 1500MWh. It would have two 125MW fixed speed turbines, a head height of between 194m and 230m and able to ramp up to maximum power in 30 seconds. However, according to a report on the Renew Economy website the power output will now be 450MW for five hours for up to 2250MWh of energy. This would involve building an upper reservoir that is 35-40 metres higher than originally planned. An associated solar PV array is also planned for the site.

The scheme could be topped up with water if necessary with via a pipeline from the Copperfield Dam 18km away. There is also an existing 132kV transmission line that connects to a substation near Townsville.



Plan of Kidston Hydro Project showing the main features of the upper reservoir, the vertical shaft from the upper reservoir, the underground power station and the transfer tunnel from the power station to the lower reservoir.



Bird's-eye view of Peter Lang's proposal for a Tantangara-Blowering Pumped Hydro Scheme.

As with all pumped hydro storage schemes water would be pumped to the upper reservoir at times of low demand and/or cheap electricity availability, and released during periods of high demand or high electricity prices.

A unique feature of this project is that it is the first to propose using disused mines for pumped storage, to minimise costs.

In addition, the facility offers a "blackstart" capability. This refers to the ability to start other power generators in the absence of grid power. This is a particular problem with wind turbines because they cannot start producing power unless there is pre-existing grid power available with which to synchronise their AC output. This factor contributed to the recent extended South Australian state-wide blackout.

The Government's Australian Renewable Energy Agency (ARENA) has committed $6.2 million to a feasibility study for this project and Genex Power Limited estimate the cost of building the facility at $282 million. They expect to commence construction this year and have it running in 2019.

Proposed Tantangara-Blowering Pumped Hydro Scheme. In 2010 an independent geologist and engineer named Peter Lang proposed an enhancement to the Snowy Mountains Hydro-electric Scheme comprising a pumped storage system that could produce 9GW for three hours per day, after pumping water for six hours. Similarly, a lesser amount of power could be produced for a longer time, eg, 1.5GW for 18 hours.

Tantangara would be used as the upper reservoir and Blowering as the lower reservoir, with a difference in elevation of 875 metres. Three 53km long, 12.7 metre diameter tunnels would be bored through to join the two reservoirs.

More details about the proposal, discussion, cost and problems can be seen at **https://bravenewclimate.com/2010/04/05/pumped-hydro-system-cost/**

Other potential sites in Australia

A number of likely sites have been identified for pumped hydroelectric storage in Australia. One is for a pumped seawater scheme in Portland, Vic, associated with the Portland Wind Farm. Another study used graphical information systems to look for suitable sites in central Tasmania and the Araluen Valley in NSW.

As well, some sites have been identified as suitable for "turkey's nest" dams based on elevation differences and horizontal distances between reservoirs but no costing or existing land use considerations were made. These include some on the Eyre Peninsula in South Australia and at Geraldton and Albany in Western Australia. The latter sites would use seawater and the sea as the lower reservoir.

A cost estimate quoted for a cliff-top "turkeys nest" site in WA for a system that can produce 700MW to 800MW for six hours is $5 billion.

In addition, other sites have been identified in northern Australia as part of a proposed scheme to export renewable energy to nearby Asian countries.

Pumped storage projects from around the world

Now let's look at some hydroelectric storage projects from around the world. The first utilises a turkey's nest as the upper reservoir and the sea as the lower reservoir and water supply. It is significant because it requires only an appropriate elevation and no natural structures that can be dammed or a supply of fresh water. The other combines solar generation with a pumped hydro storage scheme. Fluctuations in solar electric production are automatically smoothed as the power is used only to pump water and is not directly fed into the grid. Finally we look at hydraulic rock storage.

Okinawa Yanbaru Seawater Pumped Storage Power Station. This pumped hydroelectric storage power station in Japan was the first to utilise a turkey's nest reservoir in combination with the sea as its lower storage reservoir and water supply. It was built as a pilot plant with a capacity of 30MW and was commissioned in 1999. It utilises a head height of 136m and has a flow rate of 26,000 litres per second from the reservoir which has a capacity of 564 megalitres, suggesting an electrical storage capacity of 180MWh.

The system uses a variable speed turbine based upon a gate turn off (GTO) thyristor converter-inverter AC excitation system to provide maximum efficiency for both pumping and generation.

As with many such structures the surface of the reservoir in contact with water is covered with an impermeable membrane to prevent water leakage.

The Espejo de Tarapacá project in Chile is a 300MW capacity pumped hydroelectric storage project that uses seawater pumped 630 metres up to a natural depression in the Atacama Desert. It utilised three 100MW reversible Francis turbines which pump water uphill at 45,000 litres per second during the day and discharge it at night at 28,000 litres per second. The capacity of the pondage is 52 gigalites. The cost is US$400 million and construction is set to commence this year.

It will be combined with a 600MW solar PV array by 2020 and the two plants working in combination will deliver solar energy 24 hours per day, stated to be without subsidies.

Video: **https://vimeo.com/152150996**

Hydraulic rock storage

Heindl Energy GmbH (www.heindl-energy.com/) has developed a concept they called "gravity storage" or "hydraulic rock storage". It utilises a large cylinder of rock that has been carved out of the ground. The system is "charged" by having water pumped in beneath the cylinder which raises it above ground level. When energy is to be released the

Okinawa Yanbaru Seawater Pumped Storage Power Station.

water is allowed to discharge through generators to create power. The water is forced up into an above ground pond.

It has the advantage that large amounts of countryside don't have to be occupied by dams and ponds.

The economics of this concept are as follows: The storage capacity of the system depends on the mass of the rock and the height that it can be raised. If a rock cylinder is made which is the same height as its diameter the mass of the cylinder increases proportional to its radius cubed. For stability, the rock cylinder cannot be pushed out of the ground by more than half its height otherwise it could tilt.

Since the height that the cylinder can be raised is the same as the radius and since the energy storage capacity is proportional to the mass times the height the cylinder is raised (the same as the radius) we can see that the energy storage capacity increases according to the radius to the fourth power. If the radius of the cylinder is doubled the storage capacity is increased by sixteen times.

The construction of the cylinder involves cutting a circular channel to separate the cylinder from the surrounding rock and then undercutting the rock cylinder to separate it at the bottom. The circumference of the channel and base to be removed will be proportional to construction costs and doubles as the radius is doubled and the area of the base of the cylinder increases by four times as the radius is doubled for an increase of capacity of 16 times.

To be conservative we could take construction costs to scale with the more expensive of these two operations, excavating the base of the cylinder which scales with the radius squared.

Doubling the radius of the rock cylinder increases the capacity by sixteen times but the construction cost by only about four times.

The capacity of a system with a 200m diameter cylinder would be 3GWh. This would provide less than 2kW continuously, for 75,000 people, for a period of 24 hours. It would contain 2,380,000 cubic metres of water at a pressure of 67 atmospheres. The efficiency of the system would be about the same as for pumped storage, 80% or so. Such a system would rise or sink 100 metres, at around 1mm per second.

This system has a much higher energy density than a traditional pumped storage system and uses about one quarter the amount of water and much less land. It is expected to be long lived from an investment point of view, with a minimum asset life of 60 years and with low maintenance requirements.

Heindl Energy is currently planning a prototype and ways to excavate the sidewalls, the base and a sealing mechanism on the sidewalls have been conceptually determined. The pilot project has a delivery date of around 2020.

Videos on the topic: "*Hydraulic Hydro Storage for 1600GWh of energy*" **https://youtu.be/zwVMl_4QRk8**

This video shows an earlier implementation of the sealing ring system required to keep water contained.

"*TEDx Talk Hydraulic Hydro Storage*" **https://youtu.be/m3p_daUDvI8**

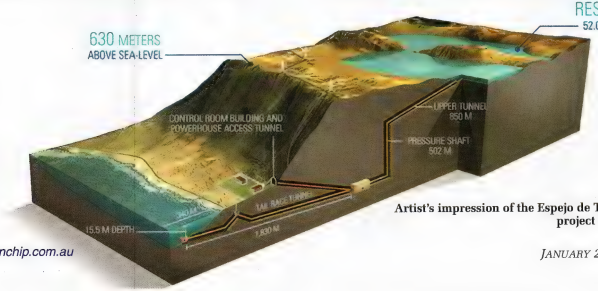
"*Comparison of different storage technologies*" **https://youtu.be/IZqUut5rNaY**

The Gravity Power Module

This concept from Gravity Power (**www.gravitypower.net/**) is similar to Heindl's hydraulic rock storage however in this case the piston does not rise above ground level. Rather than water being pumped between a ground level reservoir and beneath a rock piston as in Heindl's scheme, in this scheme water is transferred to and from beneath the piston and the area above it.

The cost of building the enormous shaft in the ground is claimed to be "surprisingly low". A Francis turbine would be used for pumping and generation.

A proposed design to provide 40MW for four hours would require a 500 metre deep main shaft of around 32.5



Artist's impression of the Espejo de Tarapacá project in Chile.

Economics

As is the case for all energy storage systems, pumped hydro-electric storage is not 100% efficient. This means that the electricity generated from release of water is less than that required to pump the water into its upper reservoir in the first place.

In some implementations of pumped storage, cheap electricity generated during off-peak times is released during peak times when the electricity price is higher.

The higher price that the electricity can be sold for during peak times more than offsets the typical 20% loss of energy involved in pumping the water to its upper reservoir as well as taking into account capital costs and running costs of the storage system.

metres in diameter, with a 250 metre tall piston of natural rock excavated from the lower 250 metres of the shaft. The adjacent power house shaft would be 10 metres in diameter.

Similar capacity and scaling considerations to the Heindl's hydraulic rock storage apply to the Gravity Power Module.

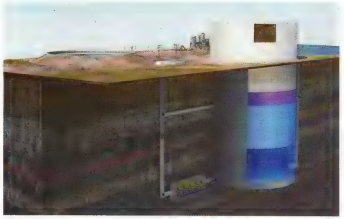
Pumped storage and wind power

While pumped storage systems do have their advantages, they do not solve the problems of intermittent energy such as solar or wind. To see why, we must consider the enormous amount of energy required by modern society and the low density of energy production of intermittent sources such as solar and wind.

Take for example the replacement of a modest 1GW fossil fuel or nuclear plant with wind turbines. As wind turbines typically operate only one third of the time or less, you would have to have three times as many windmills as their nameplate capacity would suggest.

So 3000 1MW windmills would be required to generate the same amount of energy as the fossil or nuclear plant working continuously, even before we consider how to store energy for later use when the wind is not blowing.

In the Australian context the only existing storage facility that could deliver that much power would be Tumut 3 with a presumed capacity of 70.2GWh. This could provide backup for around for a 1GW system for around 70 hours or just under three days, to account for a condition of no wind.

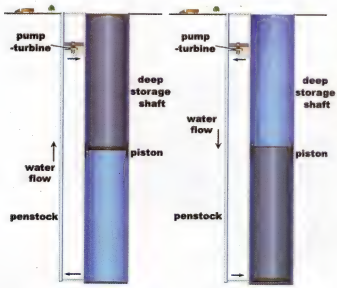


Heindl Energy's gravitational storage concept showing rock cylinder, seal (purple), water beneath rock cylinder (blue), underground pump and generator chamber and above ground pond for water.

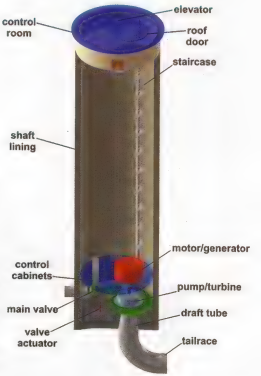
Once that storage was discharged it would take many more days to recharge the storage as noted previously and one would hope the wind would return after 70 hours and stay for a long period.

According to the Australian Energy Market Regulator there is currently an installed electrical generation capacity of 48,116MW. **If 50% of that was replaced with wind or solar, we would need 48 Tumut 3 systems as backup, even to allow for just a few days without wind or sun!**

Various storage issues have been considered for wind power and are considered at **https://stopthesethings.com/2016/08/31/bulk-battery-storage-of-wind-power-a-myth/** and **http://euanmearns.com/estimating-storage-requirements-at-high-levels-of-wind-penetration/** SC



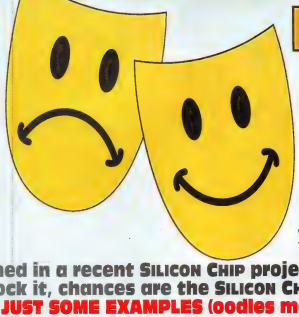
(Left): the Gravity Power Module showing water flow and position for both generating and storage modes of operation



(Right): detail of generator portion of Gravity Power Module which is located beside the storage shaft.

SAD

Because you can't find that difficult-to-get special project part at your normal parts supplier. . .
Or perhaps they've discontinued the kit you really want to build. . .



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"Viewing" Radio Waves in Colour

By Ross Tester

from billions of years ago

Imagine if you were able to "see" radio waves as they traversed the huge distances of space. A research team is using a new array in the Western Australian desert to not only view radio waves but assign them colours.

To most people in radio and electronics, frequencies above 50MHz are regarded as very high; indeed, by definition the VHF spectrum starts at 30MHz, with the Ultra High Frequency bands starting at 300MHz.

To astro-physicists, 50-350MHz are regarded as low frequencies but are an increasingly important spectrum with a large amount of research into this band being done at installations around the world.

By capturing the unbelievably feint radio signals emitted by stars and other celestial bodies at the far reaches of our (Milky Way) galaxy and beyond, they're looking for clues into how those bodies began – countless millions (or billions) of years ago – long before our Earth had evolved.

Here in Australia, the focus of such research is the Murchison Widefield Array or MWA, (a tiny section of which is shown above). This $50 million radio telescope is located at a remote site northeast of Geraldton, Western Australia.

The MWA observes low-frequency radio waves (between 70 and 320 MHz)

and was the first of the three Square Kilometre Array (SKA) precursors to be completed.

A consortium of 13 partner institutions from four countries (Australia, USA, India and New Zealand) has financed the development, construction, commissioning and operations of the facility. Since commencing operations in mid 2013 the consortium has grown to include new partners from Canada and Japan.

Key science for the MWA ranges from the search for red-shifted HI (neural hydrogen) signals from the Epoch of Reionisation to wide-field searches for transient and variable objects (including pulsars and fast radio bursts), wide-field galactic and extra-galactic surveys, plus solar and heliospheric science.

Colour views

The research is being led by Dr Natasha Hurley-Walker, of Curtin University (Perth) and the International Centre for Radio Astronomy Research (ICRAR). What makes Dr Hurley-Walker and her team's research of interest to much more than the radio astronomy community is their cataloging of 300,000 galaxies in glorious living colour – in other words, what the human eye would "see" if it could indeed view radio waves.

It's given the moniker of "GLEAM" – **GA**Lactic and **E**xtra-galactic **A**ll-sky **M**WA. In other words, the Murchison radio telescope is not simply looking into the far-flung reaches of our own Milky Way galaxy, it's looking far beyond, to the limit of currently available technology.

Normally a radio wave would just be noted as that – a radio wave, with a certain frequency and perhaps some unusual characteristics.

"The human eye sees by comparing brightness in three different primary colours – red, green and blue," Dr Hurley-Walker said. "GLEAM does rather better than that, viewing the sky in 20 primary colours."

"That's much better than we humans can manage and it even beats the very best in the animal kingdom, the mantis shrimp, which can see 12 different primary colours," she said.

GLEAM is a large-scale, high-resolution survey of the radio sky, observing radio waves that have been travelling through space – some for billions of years. The more distant the source of the radio waves, the longer they have taken to get to Earth and be detected

"Our team is using this survey to find out what happens when clusters of galaxies collide," Dr Hurley-Walker said.

"We're also able to see the remnants of explosions from the most ancient stars in our galaxy, and find the first and last gasps of supermassive black holes."

GLEAM is one of the biggest radio surveys of the sky ever assembled, with an enormous area of the sky being scanned.

Large sky surveys like this are extremely valuable to scientists and they're used across many areas of astrophysics, often in ways the original researchers could never have imagined.

Completing the GLEAM survey with the MWA is a big step on the path to SKA-low, the low frequency part of the international Square Kilometre Array (SKA) radio telescope to be built in Australia in the coming years.

The SKA

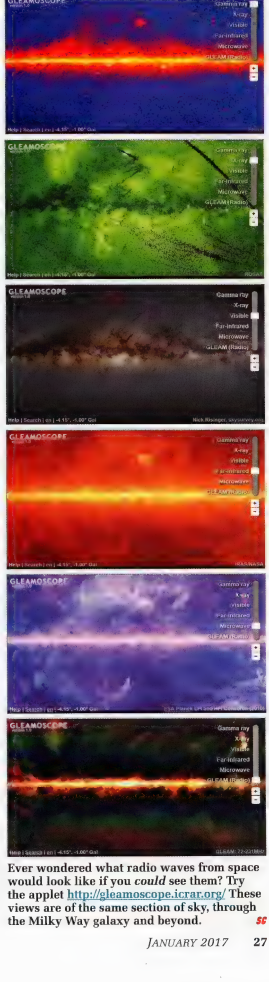
The Square Kilometre Array project is an international effort to build the world's largest radio telescope, led by SKA Organisation based at the Jodrell Bank Observatory in England.

Co-located primarily in South Africa and Western Australia, the SKA will be a collection of hundreds of thousands of radio antennas with a combined collecting area equivalent to approximately one million square metres, or one square kilometre.

The SKA will conduct transformational science to improve our understanding of the Universe and the laws of fundamental physics, monitoring the sky in unprecedented detail and mapping it hundreds of times faster than any current facility.

(SILICON CHIP featured the SKA project in the December 2011 issue and again in the July 2012 issue).

Acknowlegement: Much of the information in this feature came courtesy of Dr Natasha Hurley-Walker and the GLEAM team. (See www.icrar.org/gleam).



Ever wondered what radio waves from space would look like if you *could* see them? Try the applet http://gleamoscope.icrar.org/ These views are of the same section of sky, through the Milky Way galaxy and beyond. SC

We make it so easy to

Build the SC200...

a new, high performance amplifier module

with hardly an SMD in sight!

By
NICHOLAS VINEN
and
LEO SIMPSON

This completely new amplifier circuit incorporates most of the features of our Ultra-LD Mk4 200W amplifier module but uses easy-to-solder through-hole components. There are no tiny surface mount components.

Over the last 15 years or so, SILICON CHIP has published a number of very popular audio amplifier modules. The first of these was the SC480, described in the January & February 2003 issues.

Best described as a work-horse, this amplifier was and still is very easy to assemble and get going, and countless thousands have been have been built. Indeed, you can still purchase kits for these modules from Altronics & Jaycar.

The next very popular amplifier module was the 20W Class-A module published in 2007. We billed this as "having the lowest distortion of any amplifier ever published... anywhere in the world!"

Very keen audiophiles have built it in large numbers but being Class-A, it does have the normal drawback of being quite inefficient and therefore it dissipates a lot of heat for its modest power output of 20 watts.

Finally, the next most notable amplifier module was the Ultra-LD Mk4 design which not only has high output power but its very low harmonic distortion levels challenge even those achieved by the 20W Class-A design. Indeed, the 110W version of the Ultra-LD effectively renders the modestly-powered 20W Class-A design irrelevant.

Why would you build that Class-A design when you can build a much more powerful Class-AB design for the same money and with virtually indistinguishable performance?

So why are we producing this new SC200 module? Firstly, we have felt that while the SC480 design has been very successful, its distortion and noise performance is pretty mediocre when compared to the latter two designs. In short, it is old-hat and well overdue for a major upgrade.

Second, while the Ultra-LD Mk.4 amplifier module is virtually state-of-the-art, it does have the drawback that it uses mainly surface-mount components and while many have been built, it would have been far more popular if it used through-hole components – ones that are much easier to solder!

So in designing the SC200 module, we have tried to make it much easier to build and at the same time, produce a module which is far ahead of the SC480 in all aspects of its performance. All the semiconductors on the PCB are conventional through-hole components. Also the small-signal transistors are readily available types and while the input pair of transistors won't give quite the same extremely low noise performance of our previous Ultra-LD Mk.3 & Mk.4 designs, they are cheap and readily available.

The other major difference between the new SC200 design and the Ultra-LD Mk.4 is that it does not use the exotic five-lead On Semiconductor "ThermalTrak" NJ3281D/NJL1302D output transistors which have integral power diodes for quiescent current stabilisation. Instead, this new design uses conventional 3-lead power transistors from Fairchild, types FJA4313 and FJA4213.

While the ThermalTrak transistors are largely responsible for the excellent performance of the Ultra-LD amplifiers, they are rather expensive at $8.90 each (current retail price) and that adds up if you're building a multi-channel amplifier.

And unfortunately, as our experience has shown, they never quite delivered on their promise to provide a stable quiescent current over the operating temperature range, without the need for adjustment.

We'll discuss the new output devices more later.

Main features

The main features of this new module, which we've called the SC200, indicative of its 200-watt power output into a 4-ohm load, are very similar to those of the Ultra-LD Mk.4. And while it will replace the work-horse SC480, we would like to think its performance will be very much in the thoroughbred class!

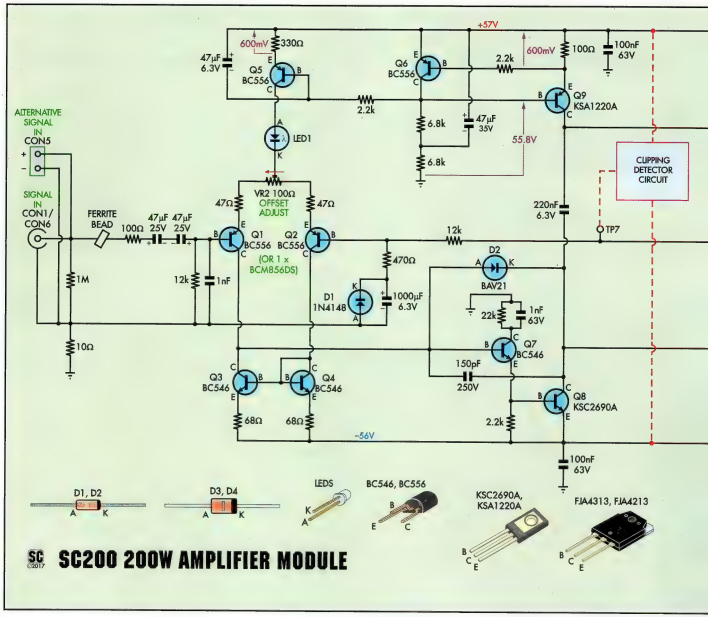
It certainly delivers more power than the SC480, for a similar price to build. Those main features are listed in a separate panel but some require additional comment.

Apart from exceptional performance, the SC200 has quite a few features which were not thought of when we produced the SC480. These include on-board LEDs which indicate if the power rails are present and which change colour if the DC fuses blow.

And there is the clipping indicator circuit which drives a LED to show when the amplifier is being over-driven. This LED can be mounted on the amplifier front panel if desired and can be wired to multiple modules to indicate when any channel is clipping. Or you can simply have a

Main features

- *Easy to build*
- *Uses low cost parts*
- *Low distortion and noise*
- *Compact PCB*
- *Able to produce specified power output on a continuous basis with passive cooling*
- *Onboard DC fuses*
- *Power indicator LEDs*
- *Fuse OK/blown indicator LEDs*
- *Clipping indicator LED*
- *Clean overload recovery with low ringing*
- *Clean square wave response with low ringing*
- *Tolerant of hum & EMI fields*
- *Survives brief short circuits & overload without blowing fuses*
- *Quiescent current adjustment with temperature compensation*
- *Output offset voltage adjustment*
- *Output protection diodes (for driving 100V line transformers and electrostatic speakers)*



clipping indicator for each channel in a stereo or surround sound amplifier.

The power output is very similar to that of the Ultra-LD Mk.4 which is to be expected as it uses the same DC supply rails and same output stage configuration.

Circuit description

The main amplifier circuit is shown in Fig.1. A 1MΩ resistor DC biases the input signal at RCA socket CON1 to 0V. The signal ground (ie, RCA socket shield) is connected to power ground via a 10Ω resistor, which improves stereo separation when modules share a power supply; it prevents a ground loop due to the grounds being joined directly both at the power supply module and at the signal source.

The signal passes through an RF attenuating RC low-pass filter (100Ω/1nF plus ferrite bead) and is coupled to the base of PNP transistor Q1 via a pair of series connected 47µF 25V electrolytic capacitors (which are together more compact and cost less than an equivalent non-polarised capacitor).

A 12kΩ resistor provides a path for Q1's base current to flow to ground. We have used readily available BC556 low-noise PNP input transistors for the input differential pair, Q1 & Q2. The input signal goes to the base of Q1 while negative feedback from the output goes to the base of Q2.

Both transistors have 47Ω emitter degeneration resistors for improved linearity and they are fed with a common 2mA current via trimpot VR2 and power indicator LED1.

VR2 allows the current split to be shifted slightly between the two transistors, to trim out base-emitter voltage mismatch and thus practically eliminate any output offset, to avoid excessive DC current when driving a line transformer or electrostatic speaker. LED1 has no effect on the operation of the circuit except to indicate when it is powered.

The currents from Q1 and Q2 go to a current mirror comprising two BC546 NPN transistors Q3 and Q4. The 68Ω emitter resistors help ensure that equal current flows through each transistor as the voltage across these resistors is much greater than the base-emitter voltage difference between the two.

Since the currents through Q3 and Q4 are held equal, any difference between the current from Q1 and Q2 must flow to the base of NPN transistor

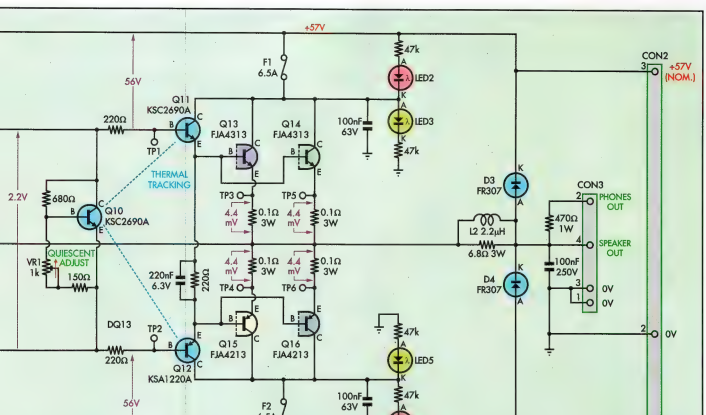


Fig.1: the complete circuit for the SC200 amplfier module minus the circuitry for the clipping detector, which is shown separately in Fig.2. Q1 and Q2 are the input transistors while Q5 and Q6 are the constant-current source. The signal from the collector of Q1 is fed to the base of Q7, which together with Q8 forms the voltage amplification stage. Q9 is the constant current load for Q8, providing very linear operation. Q10 is the V_{BE} multiplier and provides a floating voltage source which biases the complementary Darlington output stage.

Q7. Thus, Q7's base current is proportional to the difference in input and feedback voltages. It forms the first half of a compound (Darlington-like) pair along with Q8, a 160V high-gain transistor. A 2.2kΩ resistor between its base and emitter speeds up switch-off.

Q7 and Q8 together form the Voltage Amplification Stage (VAS). Q8 has a constant current source for its collector load, comprising transistors Q6 and Q9. Together, these set the collector current for Q8 at around 6.5mA. As a result, the current flow to the base of Q7 is translated linearly to a voltage at Q8's collector which controls the output stage.

PNP transistor Q5 provides a constant current of around 2mA to the input pair and both it and Q9 are driven by Q6, which is set up to maintain a constant voltage across their emitter resistors. In other words, Q6 biases the bases of Q5 and Q9 in such a way as to maintain an essentially static current through their collector/emitter junctions.

Output stage

The output stage consists of two pairs of Fairchild power transistors arranged as complementary emitter-followers. NPN transistors Q13 and Q14 are connected in parallel and source current for the speaker while Q15 and Q16 are PNP types and sink current from the speaker.

Surface-mount 3-watt 0.1Ω 1% emitter resistors ensure equal current sharing, linearise the output stage and produce a small amount of local feedback. They also serve as handy shunts for measuring the quiescent current.

Large power transistors require a substantial base current due to limited gain and this is supplied by driver transistors Q11 and Q12. These effectively make the output stage a complementary Darlington.

The parallel 220Ω resistor and 220nF capacitor between the driver emitters speed up their switch-off when drive is being handed off from one to the other.

Quiescent current stabilisation

The four base-emitter junctions in the output stage, plus the voltage across the emitter resistors adds up to around 2.2V (as shown just to the left of Q10 in the circuit diagram) and thus a similar DC bias must be maintained between the bases of Q11 and

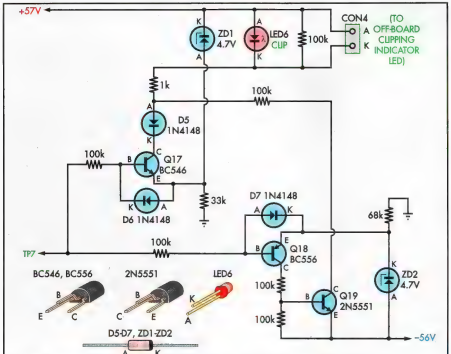


Fig.2: the clipping detector monitors the output waveform and lights LED6 whenever the output voltage comes within about 4V of either supply rail. This indicates the onset of clipping. NPN transistor Q17 detects positive signal excursions while PNP transistor Q18 detects when the output signal approaches the negative rail.

Q12 to keep the output transistors in partial conduction most of the time; otherwise, there will be substantial crossover distortion each time the signal passes through 0V.

The reason is that when the signal polarity changes (ie, from positive to negative or vice versa), the output current drive is handed off from one set of output transistors to the other; ie, from Q13 and Q14 to Q15 and Q16 or the other way around.

This transition has to be smooth or else there will be a step in the output voltage and the way to smooth it is to ensure that there is overlap between the conduction of both pairs.

In other words, with the output at zero volts, all four transistors are passing some current. This is known as the quiescent current.

This partial conduction requirement is a defining characteristic of a Class-AB amplifier (otherwise, they would be Class-B).

To maintain a more-or-less constant quiescent current we need a "floating" voltage source of 2.2V between the bases of Q11 and Q12 and this is provided by the V_{BE} multiplier Q10 and its associated components.

But since the base-emitter voltages of the six transistors in the output stage all vary with temperature, a fixed floating voltage source is not suitable.

The base-emitter voltages drop with increasing temperature at around 2mV/°C so a fixed voltage source of 2.2V would lead to increased current as the output transistors heated up and ultimately, to thermal runaway and destruction.

V_{BE} multiplier

So our floating voltage source must not only be adjustable, to compensate for manufacturing variations in the output transistors and emitter resistors, it must also automatically reduce the bias as the amplifier heats up, so that the quiescent current remains reasonably constant.

But first, let's explain the basic concept of a "V_{BE} multiplier" before we consider how it tracks and adjusts for changes in operating temperature.

The V_{BE} multiplier is sometimes referred to as an "amplified diode" and this gives some insight into its operation. Consider that the base-emitter voltage of a conducting transistor is around 0.6V. The bias network to our V_{BE} multiplier comprises the 680Ω resistor between collector and base and the 1kΩ trimpot and 150Ω resistor between base and emitter. This forms a divider between its collector and emitter, with a tap at the base.

We already know that the voltage between base and emitter is 0.6V and

Specifications

Output power (230VAC mains):	200W RMS into 4Ω, 135W RMS into 8Ω
Frequency response (10Hz-20kHz):	+0,-0.05dB (8Ω); +0,-0.12dB (4Ω);
Input sensitivity:	1.26V RMS for 135W into 8Ω; 1.08V RMS for 200W into 4Ω
Input impedance:	11.85kΩ shunted with 1nF
Rated Harmonic Distortion (4Ω, 8Ω):	<0.01%, 20Hz-20kHz, 20Hz-30kHz bandwidth
Signal-to-Noise Ratio:	-116dB unweighted with respect to 135W into 8Ω(20Hz-20kHz)
Damping factor:	~250
Stability:	unconditionally stable with any nominal speaker load ≥4Ω
Music power:	170W (8Ω), 270W (4Ω)
Dynamic headroom:	1dB (8Ω), 1.3dB (4Ω)
Power supply:	±57V DC from a 45-0-45 transformer
Quiescent current:	88mA nominal
Quiescent power:	10W nominal
Output offset:	typically <10mV untrimmed; <1mV trimmed

Parts list – SC200 Amplifier Module

1 double-sided PCB, coded 01108161, 117 x 84mm
1 diecast heatsink, 200 x 75 x 28mm (Altronics H-0536)
4 M205 fuse clips (F1,F2)
2 6.5A fast-blow M205 fuses (F1,F2)
1 small ferrite bead (FB1)
1 2.2µH air-cored inductor (L2)
(*or* 1 20mm OD x 10mm ID x 8mm bobbin and 1m of 1.25mm diameter enamelled copper wire, plug 10mm length of 20mm diameter heatshrink tubing)
1 1kΩ 25-turn vertical trimpot (VR1)
1 100Ω mini horizontal trimpot (VR2)
1 switched horizontal RCA socket (CON1) OR
1 2-pin polarised header (CON5) OR
1 vertical RCA socket (CON6)
1 4-way pluggable terminal block with socket, Dinkle 4EHDV or equivalent (CON2)
1 4-way pluggable terminal block with socket, Dinkle 3EHDV or equivalent (CON3)
4 TO-3P insulating washers
3 TO-126 or TO22- insulationg washers
7 15mm M3 machine screws with nuts
6 6mm M3 machine screws with nuts
4 9mm M3 tapped nylon spacers
8 PCB pins (optional; TP1-TP7)

Semiconductors
2 FJA4313 250V 17A NPN transistors, TO-3P (Q13,Q14)
2 FJA4213 250V 17A PNP transistors, TO-3P (Q15,Q16)
3 KSC2690A medium power NPN transistor (Q8,Q10,Q11)
2 KSA1220A medium power PNP transistors (Q9,Q12)
3 BC546 NPN transistors (Q3,Q4,Q7)*
4 BC556 PNP transistors (Q1,Q2,Q5,Q6)*
1 blue 3mm or SMD 3216/1206 LED (LED1)
2 red 3mm or SMD 3216/1206 LEDs (LED2,LED4)
2 green 3mm or SMD 3216/1206 LEDs (LED3,LED5)
1 1N4148 small signal diode (D1)*
1 BAV21 high-speed signal diode (D2)*
2 FR307 3A fast-recovery diodes (D3,D4)

Capacitors
1 1000µF 6.3V electrolytic
1 100µF 63V electrolytic
1 47µF 35V electrolytic
3 47µF 25V electrolytic
2 220nF 50V multi-layer ceramic or MKT
1 100nF 250VAC MKP
4 100nF 63V/100V MKT
2 1nF 63V/100V MKT
1 150pF 250V C0G/NP0 ceramic or MKT/MKP

Resistors (all 0.25W, 1% unless otherwise specified)
1 1MΩ 4 47kΩ 1 22kΩ 2 12kΩ 2 6.8kΩ 3 2.2kΩ 1 680Ω
1 470Ω 1W 5% through-hole or SMD 6332/2512
1 470Ω 1 330Ω 3 220Ω 1 120Ω
1 100Ω 1W 5% through-hole or SMD 6332/2512
2 100Ω 2 68Ω 2 47Ω 1 10Ω
1 6.8Ω 1% 3W SMD 6332/2512
4 0.1Ω 1% 3W SMD 6332/2512

** SMD versions can be substituted; see text next month*

since the beta (DC current gain) of the transistor is quite high (>100), it will draw negligible base current, so the current through the two resistors and trimpot VR1 will essentially be identical. Furthermore, since we will have 0.6V between base and emitter, it follows that we need 1.6V between collector and base, if we are to obtain 2.2V between collector and emitter.

So, to adjust the resistance of VR1 to obtain 1.6V between collector and emitter, we need a resistance ratio between collector/base and base/emitter of 1.6V÷0.6V or 2.6666:1. This means the total resistance of VR1 and its series 150Ω resistor will be 680Ω x 0.6÷1.6 = 255Ω. And that means that trimpot VR1 must be set to a value of 255Ω -150Ω = 105Ω.

We can therefore calculate the total resistance of the divider between collector and emitter at around 255Ω + 680Ω = 935Ω and therefore 2.2V / 935Ω = 2.35mA will flow through it.

The remainder of the 6.5mA, ie, 4.15mA must flow through the collector/emitter junction of Q10.

But what if the external operating conditions around the V_{BE} multiplier act to increase the voltage between its collector and emitter above 2.2V? If that did happen, the resistive divider would cause its base-emitter voltage to increase but that would force the transistor to turn on harder and that would have the effect of reducing the collector-emitter voltage.

So the V_{BE} multiplier transistor is instead forced to operate with a constant collector-emitter voltage! In other words, it operates as a shunt voltage regulator, maintaining a constant voltage across the collector/emitter

Additional parts for clipping detector circuit

1 2-pin header and matching plug (optional; CON4)

Semiconductors
1 BC546 NPN transistor (Q17)*
1 BC556 PNP transistor (Q18)*
1 2N5551 high-voltage NPN transistor (Q19)
1 yellow, amber or red LED (LED6)
2 4.7V 0.4W/1W zener diodes (ZD1,ZD2)*
3 1N4148 small signal diode (D5-D7)*

Resistors (all 0.25%, 1%)
6 100kΩ 1 68kΩ 1 33kΩ 1 1kΩ

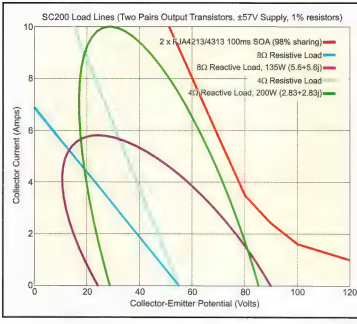


Fig.3: this diagram shows resistive (straight) and reactive (curved) load lines for operation into loudspeaker loads. Note that all the load lines are comfortably inside the safe operating area (SOA – red line) of the paralleled output transistors.

junction even if the current passing through it varies (but as long as it's higher than the 2.35mA required for the divider to operate properly).

Thermal tracking

So how does V_{BE} multiplier transistor Q10 adjust for temperature changes in the output transistors? We make it do that by mounting Q10 on the heatsink immediately between driver transistors Q11 and Q12. Furthermore, Q10 is the same transistor type as Q12, so the thermal tracking of the driver transistors and by extension, that of the four output power transistors, is quite good; not perfect but quite good.

So if the temperature of the heatsink rises by 50°C, that would mean that the required base-emitter voltages of all seven transistors (for a given collector current) on the heatsink will reduce by 50 x 2mV = 100mV.

If the base-emitter voltage of Q10 has reduced by 100mV, given that it operates with a gain of (1.6 + 0.6)÷0.6 = ~3.7 times, the voltage of our floating source will be reduced to 2.2V – 100mV x 3.7 = 1.83V and this voltage will be applied across the four base-emitter junctions of the complementary Darlington output stage transistors. That means that even though the transistor junction temperatures may have increased by 50°C, their quiescent current should remain much as it was at much lower temperatures.

In practice, the process is not quite that good so we also have local feedback provided by the 0.1Ω 3W emitter resistors for the output transistors. If the voltage across these emitter resistors increases, due to increasing quiescent current, that will tend to reduce the base-emitter voltage (by subtraction) and therefore the current will reduce (or at least, not increase by as much as it would without them).

By the way, the 220Ω resistors between either end of the Vbe multiplier Q10 and Q11/Q12 act as RF stoppers and also limit current flow under fault conditions (eg, a short circuit).

Feedback & compensation

Negative feedback goes from the junction of the output emitter resistors to the base of Q2 via a 12kΩ/470Ω resistive divider, setting the closed loop gain to 25.5 times (+28.5dB). The bottom end of the feedback network is connected to ground via a 1000µF electrolytic capacitor.

This has a negligible effect on low-frequency response but sets the DC gain to unity, so that the input offset is not magnified at the output by the gain factor of 25.5.

The 150pF compensation capacitor is connected between the collector of Q8 and the base of Q7, ie, it is effectively a Miller capacitor for the VAS "Darlington" (in a real Darlington, the collectors would be common). This is a single-pole compensation arrangement which rolls off the open-loop gain at a high frequency to give unconditional stability with highly reactive loads across the amplifier's output.

The 22kΩ resistor in series with the collector of Q7 limits its current under fault conditions. Should the amplifier outputs be shorted, it will try to pull the output either up or down as hard as possible, depending on the offset voltage polarity.

If it tries to pull it up, the output current is inherently limited by the approximate 6.5mA current source driving Q11 from Q9. However, if it tries to pull down, Q8 is capable of sinking much more than 6.5mA.

The 22kΩ resistor limits Q8's base current to around 2mA and since Q8 has a beta of around 120, Q8's collector will not sink much more than 240mA. This is still enough to burn out Q12's 220Ω base resistor but that may be the only damage from an extended short circuit; very brief short circuits will should not cause any lasting damage.

Note that the 22kΩ resistor will cause Q7's collector voltage to drop as it is called on to supply more current and the Early effect means its gain will drop when this happens. This can cause local negative feedback and oscillation. A low-value capacitor in parallel with the 22kΩ resistor prevents this while still allowing the current to Q8's base to quickly drop to 2mA during a short circuit.

Output filter

The 0.1Ω 3W emitter resistors of output transistors Q13-Q16 are connected to the output at CON3 via an RLC filter comprising a 2.2µH series inductor in parallel with a 6.8Ω 3W surface-mount resistor, with a 100nF capacitor across the output terminals. The inductor isolates any added capacitance at the output (eg, from the cables or the speaker's crossover network) from the amplifier at high frequencies, which could otherwise cause oscillation. The resistor reduces the inductor's Q, to damp ringing and also forms a Zobel network in combination with the 100nF capacitor, which also aids stability.

Driving a line transformer

While a very low output offset voltage gives slight benefits when driving normal speakers, it's absolutely critical when driving a 100V line transformer (for professional PA applications) or electrostatic speaker (which will typically have an internal transformer).

That's because the DC resistance of the primary winding will be much lower than that of a loudspeaker's voice coil, so a lot of DC current can flow with an output offset voltage of

WARNING!

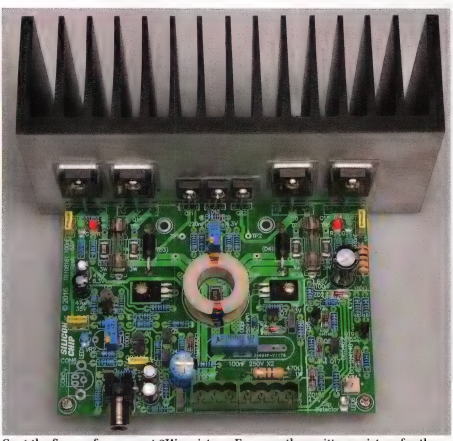
High DC voltages (ie, ±57V) are present on this amplifier module. In particular, note that there is 114V DC between the two supply rails. Do not touch any wiring (including the fuseholders) when the amplifier is operating, otherwise you could get a lethal shock.

just a few millivolts.

The other requirement for driving a transformer is to have protection diodes on the amplifier output to clamp inductive voltage spikes which occur when the amplifier is driven into clipping (overload).

These would otherwise reverse-bias the output transistor collector-emitter junctions, possibly causing damage. D3 and D4 are 3A relatively fast recovery diodes with low junction capacitance for their size and we have checked that they do not have any impact on performance.

So there should be no changes necessary to use this module in a PA amplifier or to drive electrostatic speakers, as long as the output offset voltage is trimmed out during set-up.



Spot the five surface-mount 3W resistors. Four are the emitter resistors for the output transistors and the fifth is inside the output inductor.

Indicator LEDs

We have already mentioned a blue LED1 connected in series with the input pair current source and which is lit while ever the board has power applied. Since there is an ~50V drop required from Q5's collector to VR2's wiper, the power to operate this LED is effectively free.

We've also included red/green LEDs LED2-LED5 to indicate the status of the output stage power rails. It isn't always obvious that a fuse has blown without careful inspection.

In the case of LED2, assuming F1 has not blown, the voltage at either end of the fuse-holder is the same so no current will flow through the red junction. However, LED3is connected between the collectors of Q11, Q13 and Q14 and ground via a 47kΩ current-limiting resistor, so it will light up.

If fuse F1 blows, the collector voltages will drop to near 0V, so green LED3 will turn off but the full rail voltage will be across the fuse-holder and so the red LED2 will switch on. Similarly, LED5/LED4 indicates green/red when F2 is OK/blown.

These LEDs will also indicate if one of the two supply rails is missing (eg, due to a wiring fault); in this case, LED1 will probably still light up so it might not otherwise be obvious.

Clipping indicators

Now we can talk about the on-board clipping detector/indicator circuit. This involves just a few components and will indicates whenever the amplifier is driven into clipping, which may not be obviously audible.

It can drive an external LED mounted on the front panel of the amplifier. These components may be omitted if they are not required.

The clipping detector circuit is shown in Fig.2. Zener diode ZD1 derives a reference voltage 4.7V below the nominally 57V positive rail, ie, at about +52V. This is connected to the emitter of NPN transistor Q17. Its base is connected to the amplifier's output via a 100kΩ current-limiting resistor, with diode D6 preventing its base-emitter junction from being reverse-biased.

At the onset of clipping, the speaker voltage will rise above the +52V reference plus Q17's base-emitter voltage, ie, to about +53V. Q17 will switch on and sink current via LED4, a 1kΩ current-limiting resistor and isolating diode D5, lighting up clipping indicator LED6. As the reference voltage is relative to the positive rail, any variations in supply voltage will be accounted for.

ZD2, PNP transistor Q18 and diode D7 work in an identical manner for negative excursions.

However, Q18 drives LED6 via high-voltage NPN transistor Q19 which acts as a level shifter. The 100kΩ resistor in series with its collector limits the LED current to a similar level (1mA) despite the much higher rail voltage differential.

This is not the simplest clipping detector circuit but it presents an almost completely linear load to the amplifier output, to minimise the possibility of any distortion due to its input load current.

It's connected to the driven end of L2, to give the amplifier the best chance to cancel out any non-linearities in the load it introduces.

Next month

Have we whetted your collective appetites? Next month we will present the full details of performance and construction details. SC

Design by JOHN CLARKE

Our biggest-ever DC speed controller: 12 to 60V at up to 40A!

So you need a speed controller for a powerful DC motor. How much grunt do you want? This design has bags of it and can run with a DC supply from 12V to 60V, at currents up to 40A. As well, it has low battery cut-off, speed regulation (feedback), soft start and other useful features.

unt?

Features

- Operation up to 60V at currents up to 40A
- High or low-side switching
- Hall Effect or potentiometer throttle
- Soft start at power up
- Emergency stop button with LED indicator
- Low battery shut down with LED indicator
- LED power and speed indication
- Speed regulation with motor feedback
- Minimum and maximum throttle range adjustment
- Maximum speed limit setting
- PWM frequency adjustment from 100Hz to 1kHz (typical)

The 24V 20A speed controller published in our June 2011 issue has been extremely popular and reliable over the years and it is still a valid design if you want a fairly modest power output.

We also published a more complex 12-24V 40A design with a 4-digit display in the March & April 2008 issues but its complicated set-up made it less popular with readers.

But now we have come up with a new design which can be regarded as our June 2011 design on steroids.

Not only will it work with much higher battery voltages, up to 60V (equivalent to a 48V lead-acid battery) and at currents up to 40A, it has a wide range of features which will make it much more flexible.

What sort of motors can you use with this speed controller? Answer: any brushed DC motor; permanent magnet, series-wound or shunt-wound and with current ratings up to 40A.

Features

One drawback of all our past DC speed controllers is that one side of the motor needs to be tied to the positive side of the battery. This is a problem in car applications because in those cases, one side of the motor is tied to chassis. Our new design caters for either situation, depending on link options on the PCB.

Our new design provides good speed regulation as it monitors the motor back-EMF. Back-EMF is the voltage generated by the motor which opposes the current flow.

Motor back-EMF increases in proportion to the motor speed and so it can be used to provide good speed regulation.

Soft start is another desirable feature which means that the motor does not start with a sudden jerk as soon as power is applied. Instead, it can be programmed to start very gently or very rapidly, depending on the setting of a trimpot.

The speed of the motor can be adjusted using a standard potentiometer (ie, via a rotary knob) or via a twist-grip (Hall Effect) throttle, as on electric bikes. There is also a flashing LED which gives a visible indication of the speed setting, with short flashes meaning low speed and longer flashes indicating high speed.

Maximum speed setting

Often you need to limit the speed at which a motor can run and in this design it is simple to set.

As with our other DC speed controllers, this circuit works on the pulse-width modulation (PWM) principle which means that it controls the power by rapidly switching two or three paralleled Mosfets on and off.

And since PWM speed controllers can result in an audible whine from the motor, we provide a trimpot to adjust the PWM frequency so you can tune it to minimise audibility of the switching.

We should also state that some motors will work better at low PWM rates since they may have high inductance.

Others may work well at higher frequencies but the switching noise becomes more audible. Hence, setting

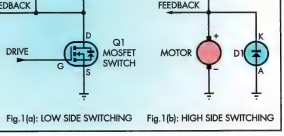


Fig.1: these two circuits show the difference between high side and low side switching. This refers to the position of the control circuitry and motor with respect to the supply. In low side, the motor is switched, or controlled, between its negative connection and earth; in high side between the motor positive and the positive supply.

Fig.1(a): LOW SIDE SWITCHING Fig.1(b): HIGH SIDE SWITCHING

the PWM frequency is a compromise for the particular motor you are using.

Emergency stop

This feature is self-explanatory. Hit a switch and motor will stop immediately. If you don't need it, you can leave the switch out.

Emergency stop operates in one of two modes. The first will restore normal operation once the throttle is returned to zero. The second will only restore normal operation when power is switched off and on again.

Finally, to prevent the battery being discharging too deeply and causing permanent damage, there is a low battery cut-off trimpot. For example, with a 12V battery, you might have a cut-off setting at 11.5V. Going below that with sealed lead acid batteries can cause battery failure.

Two PCBs

The speed controller is mounted in a compact diecast aluminium case with four high-current binding post terminals, two for the battery connections and two for the connections to the motor.

On the side of the box are four LEDs, to indicate Power, Speed, Low Battery and Shutdown/Limit. There is also a toggle power switch and the speed control knob.

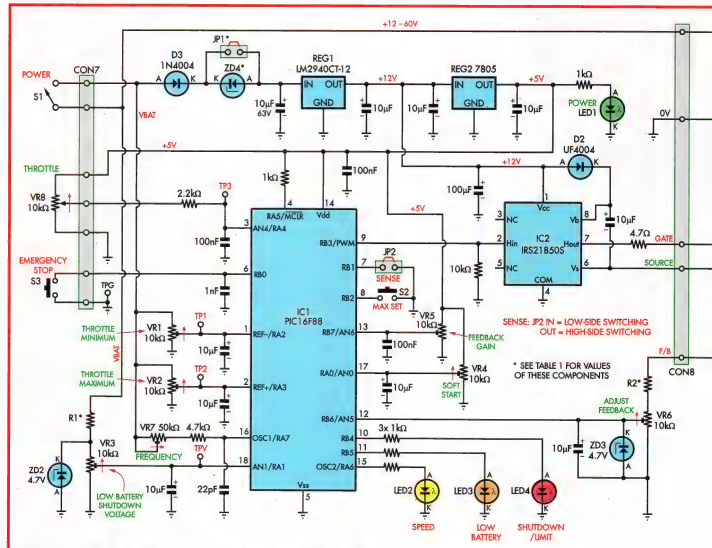
Inside the box are two PCBs, one sitting on the base and one attached to the lid.

The PCB on the base is the control board, carrying the microcontroller and the eight trimpots and this is linked to the lid-mounted switching PCB which has the fuseholder, Mosfets and the four binding post terminals.

High side & low side switching

We have already mentioned that this circuit can work with one side of the motor tied to the positive side of the battery and it will also work with one side of the motor tied to the negative side of the battery, which is the case with most, if not all, the DC motors used in cars.

Where the motor is connected to the positive side of the battery, the Mosfet doing the PWM switching is connected



SC ©2017 HIGH POWER DC MOTOR SPEED CONTROLLER

Fig.2: the circuitry on this page is that on the "control" PCB. IC1, a PIC16F88, monitors the settings of the various controls, along with monitoring the back-emf from the motor. It produces the PWM signal used to control the motor speed. . .

between the negative terminal of the motor and the negative terminal of the battery. We refer to this as "low side switching" and this is depicted in the circuit of Fig.1(a). This configuration has been used in most of our previous DC speed controls.

As you can see, the Mosfet is below the motor, on the "low side".

In the opposite case, the motor is connected to the negative terminal of the battery and the switching Mosfet is connected between the positive terminal of the battery and the positive terminal of the motor and this "high side switching" arrangement is shown in Fig.1(b).

Arranging the gate drive signals to an N-channel\ Mosfet in a low-side switching circuit is comparatively simple since the source of the Mosfet is at 0V and this is easy with typical logic or microcontroller switching.

It is somewhat more complicated in a high-side switching circuit since the source terminal of the Mosfet is tied to that of the positive motor terminal and so when the motor has full voltage applied to it, the Mosfet's source voltage is almost equal to the battery voltage.

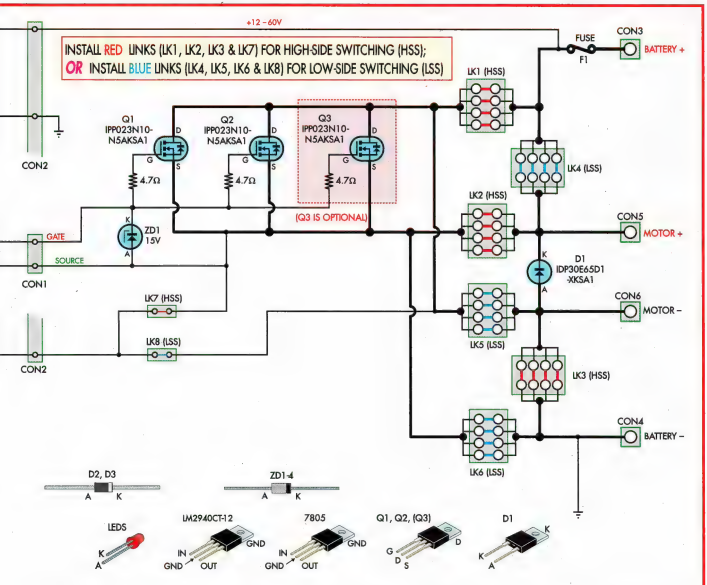
But when the motor has low or zero voltage applied to it, the Mosfet's source voltage is similarly low. This creates a problem with an N-channel Mosfet since it needs a gate voltage which is positive with respect to the source.

Consider then, a circuit with a nominal battery voltage of 48V and a Mosfet which requires a gate-source voltage of say, 10V to fully turn on. That would mean that the required gate voltage was about 58V, ie, 10V more than the battery voltage. How do you generate such high gate voltages which are tied to the source terminal and which need to "float up an down" according to whether the Mosfet is turned on or off?

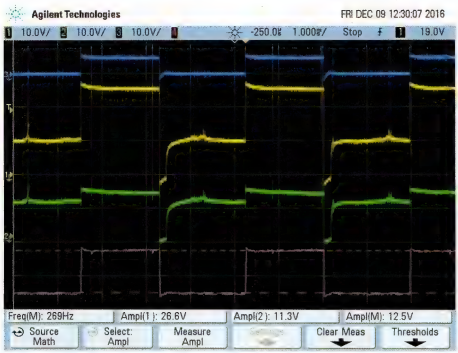
That task is performed by a "high-side driver" IC, so we have one of those chips in our circuit, which we will now describe.

Circuit description

The full circuit of the motor speed controller is shown in Fig.2. The section on the left-hand page is that on



. . . while the circuitry on this page is all on the "switching" PCB to actually drive the motor. As mentioned in the text, it is absolutely imperative that you ONLY install the red OR the blue links, depending on high or low-side switching.



These waveforms show the operation of the speed controller. The top (blue) trace is the PWM waveform from IC1. The yellow trace is the "jacked up" gate waveform from the high-side driver, IC2. The green trace is the voltage across the motor – note that it is smaller in amplitude than the gate waveform. Finally, the pink trace is the gate-source waveform (difference between traces 1 & 2).

the control PCB and it includes the PIC16F88 microcontroller (IC1), the International Rectifier IRS21850S high/low side driver (IC2), two 3-terminal regulators and seven trimpots.

The section on the right-hand page is that of the switching PCB and includes the two (or three Mosfets), the fast recovery diode (D1) and the all-important links which set the circuit up for high-side or low-side switching.

We will make this point up-front: It is absolutely crucial that you only install one set of links for high-side OR low-side switching.

If you (stupidly!) install all the links, you will have created a short-circuit directly across the battery which will blow the fuse to smithereens as soon as the circuit is connected!

With that point out of the way, we will continue with the circuit description.

Starting on the left-hand side of the circuit, the microcontroller monitors the speed input signal from a potentiometer (VR8) or a twist-grip Hall Effect throttle and produces a 5V pulse-width modulated (PWM) signal which is fed to IC2 where it is converted to a floating 0-12V signal suitable for the gates of either low or high-side connected Mosfets.

The speed signal from potentiometer VR8, ranging from 0 to 5V, is fed to the AN4 input of IC1 via a 2.2kΩ resistor. IC1's analog to digital converter (ADC) converts the speed signal to digital form.

The ADC has two reference inputs, REF- and REF+. These references provide the range over which the ADC measures and they are set using trimpots VR1 and VR2, respectively.

If a Hall Effect throttle is used, its output does not cover the full 0-5V range. So in this case, VR1 is used to set REF- to match the lowest voltage available from the Hall Effect throttle and VR2 is used to set REF+ for the highest voltage from the sensor. The digital result from the ADC then covers the full 0-255 range.

REF+ and REF- do have limit restrictions. REF+ can be set between 2.5V and 5V, while REF- can be from 0V up to 2V below REF+. So for a Hall Effect throttle that has a 0.75V minimum and 3.65V maximum, REF- is set for 0.75V and REF+ set to 3.65V. These values are within the voltage limit restrictions.

So depending on the throttle setting, IC1's PWM output at pin 9 produces a 5V pulse stream with a duty cycle ranging from 0% (Off) to almost 100%. It does not go to the full 100% (ie, 5V), as will be explained later.

LED2, connected to pin 15 of IC1, flashes to mimic the duty cycle of the PWM signal; brief flashes at low speed settings and longer flashes for higher speed settings.

ADC references

While the throttle input at AN4 uses the REF+ and REF- settings from VR1 and VR2 as discussed above, the remainder of the analog inputs to IC1 are converted using alternative references set up within the software.

The first of these is for low battery detection. The AN1 input, pin 18, monitors the battery voltage via resistor R1 and trimpot VR3. The input voltage to IC1 is limited by the 4.7V zener diode, ZD2. Table 1 shows the value of R1, depending on the nominal battery voltage.

The battery voltage is deemed to be low when the voltage at AN1 falls below 2.5V, assuming an exact 5V at pin 14 of IC1. If the voltage at AN1 drops below 2.5V, the Mosfets are turned off and LED3 is lit up.

This condition will stay until the circuit is turned off and the battery voltage is increased (charge the battery?). Shutdown will re-occur if the battery voltage is still below the low battery setting.

Speed regulation feedback

One of the tricky aspects of this circuit is providing for feedback of the motor back-EMF. As already noted, the back-EMF is proportional to the speed of the motor and it opposes the current. So when the motor is stalled (but voltage is applied) there will be no back-EMF and the current will be very high (this is the stall or locked-rotor current).

Conversely, when motor speed is high, the back-EMF will be high and the current will be correspondingly low. For example, with an applied voltage of 12V and the motor running at maximum speed, the back-EMF could be as high as 10V.

A further complication applies depending on whether the circuit is configured for high-side or low-side switching of the Mosfets. In the high-side switching case (see Fig.1(b)), the back-EMF will vary from 0V to, say, 10V, with the DC supply being 12V.

That can be quite simply coupled back to the microcontroller. But in the low-side switching case, since one side of the motor is tied to the +12V rail, the back-EMF will vary from 12V (zero

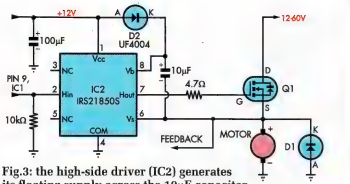


Fig.3: the high-side driver (IC2) generates its floating supply across the 10µF capacitor in a bootstrap mode, enabled by the switching of Mosfet Q1.

speed), to 2V (full speed). In other words, the back-EMF will be tied to the positive rail and will have the opposite sense.

There are two ways to cope with this problem. One method is to build a level-shifting inverting op amp circuit but op amps that can cope with a supply voltage and common mode voltages running to 60V or more are expensive and hard to get. The way around this is to use level-shifting circuit using discrete transistors and this approach was presented in the Circuit Notebook pages of the December 2016 issue.

In this case though, we just reduce the back-EMF voltage to no more than 5V and let the microcontroller figure it out. So, looking for a moment at the right-hand side of the circuit, we take the feedback (back-EMF signal) from the commoned source electrodes of the Mosfets (positive side of the motor) via link LK7 for the high-side switching circuit and from the commoned drain electrodes of the Mosfets via link LK8.

The feedback signal is fed via resistor R2 to the "Adjust Feedback" 10kΩ trimpot VR6. The voltage from the wiper of VR6 is limited by 4.7V zener diode ZD3 and filtered to remove motor hash by the 10µF capacitor and then fed to pin 12 of the microcontroller, IC1.

The value of R2 is varied according to the supply voltage, as shown in Table 1 below.

Table 1: resistor, zener and jumper settings for various battery voltages.

Nominal supply voltage	R1 & R2	JP1	ZD4
12V	10kΩ	Jumper inserted	No zener
24V	27kΩ	No jumper	10V 1W
36V	47kΩ	No jumper	20V 1W
48V	68kΩ	No jumper	30V 3W

We need to tell the microcontroller whether the circuit is high-side or low-side switching and that is done with SENSE jumper link JP2, connected to the RB1 input at pin 7.

Normally, the sense input is held high (5V) via an internal pullup current and in that condition, the software works for a high-side driver. If the sense input is tied to 0V with link JP2, then software works for low-side switching.

Speed limiting and PWM frequency

You can set the maximum motor speed in the following way. Press the speed limit switch S2 (connected to the RB2 input, pin 8) and set the throttle to the desired maximum speed and then release the switch. Once the maximum speed is set in this way, you can apply more throttle but the duty cycle of the Mosfet switching will not increase beyond the limit.

IC1's PWM output switching frequency at pin 9 is set by 50kΩ trimpot VR7, the 4.7kΩ series resistor and the 22pF capacitor connected to pin 16, the RC oscillator clock input. VR7 allows you to set the PWM frequency over the range from 100Hz to 1kHz, as previously noted.

Inside the Motor Speed Controller – full construction details will be presented next month but will be slightly different from this prototype. The links on the motor PCB have been set up for high-side operation.

Mosfet switching

The PWM output signal from IC1 is fed to IC2 and it can drive the N-channel Mosfets in high-side or low-side switching without any circuit changes being required.

Fig.3 (above left) shows a portion of the circuit of Fig.2. The PWM signal from IC1 is fed to pin 2 and IC2's pin 7 drives the gate (or gates) of the Mosfets. IC2 has an internal floating supply that can raise its output up to 600V higher than the 12V supply rail, Vcc, applied between pins 4 & 1.

The internal floating supply is between VB and Vs and is essentially a "bootstrapped" diode pump circuit. It depends on the Mosfet and load (in this case the motor) being connected. The Mosfet source connects to Vs (pin 6)and the gate connects to pin 7. With the Mosfet initially off, diode D2 charges the 10µF capacitor that's between pin 8 (Vb) and pin 6 (Vs) via the motor windings. At this point, the floating supply is sitting at about 12V and can provide a 12V gate signal to the Mosfet.

When the Mosfet gate is taken to 12V, it switches on

Parts List – DC Motor Speed Controller

Controller board
1 PCB, coded 11112161, 107 x 82mm
1 set of panel labels
1 diecast box 119 x 94 x 57mm (Jaycar HB-5064)
2 3-way screw terminals with 5.08mm spacings (as part of CON7 & CON8)
3 2-way screw terminals with 5.08mm spacings (as part of CON7 & CON8)
1 SPST toggle switch (S1)
1 emergency shut-down switch latching DPDT pushbutton; S3; optional (Altronics S 0820)
1 momentary PCB-mount switch (Jaycar SP-0601, Altronics S1120; S2)
1 DIL18 IC socket
2 2-way pin headers with 2.54mm spacings (JP1,JP2)
2 jumper shunts
1 knob to suit speed potentiometer
4 rubber feet
4 M3 tapped x 6.3mm spacers
10 M3 x 6mm screws
2 M3 nuts
1 cable gland for 4-8mm cable
1 500mm length of medium duty hookup wire (or 5 100mm lengths of medium duty hookup wire of different colours)
8 100mm cable ties
5 PC stakes (optional)

Semiconductors
1 PIC16F88-I/P microcontroller programmed with 1111216A.hex (IC1)
1 IRS21850SPBF high-side driver (IC2)
1 LM2940CT-12 low dropout regulator (REG1)
1 7805 three terminal regulator (REG2)
4 5mm LEDs (LED1 [green], LED2 [yellow], LED3 [amber], LED4 [red])
1 UF4004 1A fast diode (D2)
1 1N4004 1A diode (D3)
1 zener diode (ZD4) (see table 1)
2 4.7V 1W zener diodes (ZD2,ZD3)

Capacitors
1 10µF 63V PC electrolytic
9 10µF 16V PC electrolytic
1 100µF 16V PC electrolytic
3 100nF 63V or 100V MKT polyester
1 1nf MKT polyester
1 22pF ceramic

Resistors (0.25W, 1%)
1 10kΩ 1 4.7kΩ 1 2.2kΩ 5 1kΩ 1 4.7Ω
R1,R2: see Table.1
6 10kΩ miniature horizontal trimpots (code 103) (VR1-VR6)
1 50kΩ miniature horizontal trimpot (code 503) (VR7)
1 10kΩ linear potentiometer (VR8)

Power board
1 PCB coded 11112162, 111 x 85mm (70µm copper)
2 50A red Jumbo binding posts (Altronics P9225) (CON3,CON5)
2 50A black Jumbo binding posts (Altronics P9226) (CON4,CON6)
1 40A PCB mount standard ATO/ATC blade fuse holder (Altronics S6040) (F1)
1 40A* ATO/ATC blade fuse (*rating to suit motor)
1 3-way screw terminals with 5.08mm spacings (CON2)
1 2-way screw terminals with 5.08mm spacings (CON1)
1 200mm length of 0.7mm tinned copper wire
1 600mm length of medium duty hookup wire (or 6 100mm lengths of medium duty hookup wire of different colours)
2 M3 tapped spacers, 12mm long
5 M3 x 10mm screws

2 IPP023N10N5AKSA1 120A 100V N-channel Mosfets (Q1,Q2)
1 IDP30E65D1XKSA1 60A 650V diode (D1)
1 15V 1W zener diode (ZD1)
2 4.7Ω 0.25W resistors

and its source is pulled up to the positive battery supply. The source voltage pulls the negative side of the 10µF floating supply to the battery voltage (which can be up to 60V in our circuit) and the positive side of the 10µF capacitor is then 12V above the battery supply. Diode D2 is then reverse-biased.

When the gate signal drops to zero, the Mosfet switches off and the 10µF capacitor is recharged 12V. In this way, IC2 can always deliver an adequate gate pulse voltage to turn on the Mosfet and drive the load.

However, for this process to work, the gate pulses can never have a duty cycle of 100%, ie, permanently high, because that would stop the diode pump involving D2 from working. In practice, the PWM duty cycle can reach 99% without the floating supply discharging. This is why the PWM duty cycle can not ever reach 100%, as noted earlier in this article.

In the low-side switching configuration, the floating supply in IC2 remains at ground level, due to Vs being connected to ground. IC2 is then used as a high current Mosfet gate driver that translates the 0-5V from the PWM output of IC1 to 0-12V.

High-side & low-side switching configurations

It may not be obvious, but the change from low-side switching as shown in Fig.1(a), to high-side switching in Fig.1(b), is done by two sets of links and as already noted, only one set of these links must be installed on the PCB.

So for the high-side switching, you would install the parallel links LK1, LK2 & and LK3, as well as the feedback link LK7.

Similarly, for low-side switching, you must install paralleled links LK4, LK5 & LK6, together with feedback link LK8. These linking options essentially swap the positions of the Mosfets and motor, to agree with Fig.1(a) or Fig.1(b).

Next month we will complete the DC Motor Speed Controller with the construction details and setting up procedure. SC

SERVICEMAN'S LOG

When spare parts aren't around

Dave Thompson*

Some things just aren't made like they used to be. When tools break you would expect that it would be cheaper for the manufacturer to supply spare parts than expect the consumer to buy a new tool.

Items Covered This Month

- Nail gun – replace or repair?
- Medion computer
- Roberts DAB radio
- Toyota RAV4 speedo fault

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Some of my earliest and happiest memories are of being in my father's workshops. I say workshops, because like many engineering types, he had several different shops over the course of his working life. The first I remember was literally on the "other side of the tracks" in an area that was considered a little bit, well, industrial.

At that time, Dad was making materials for a fishing rod manufacturer. He'd designed and built a machine – his lifelong specialty – that took multiple threads of glass fibre from huge spools and pulled them through a heated mould. Depending on which mould was being used, either a solid or tubular fiberglass rod magically emerged from the other end.

This machine almost certainly dictated the type of workshop required due to its bulk, and was why this particular location worked out so well.

He also did a lot of other work from that workshop. For as long as I can remember he was the neighbourhood's go-to guy for fixing everything from TVs to talking dolls. These were the days, the mid-sixties, when people actually held onto the stuff they had, as opposed to just chucking it away and buying a new one.

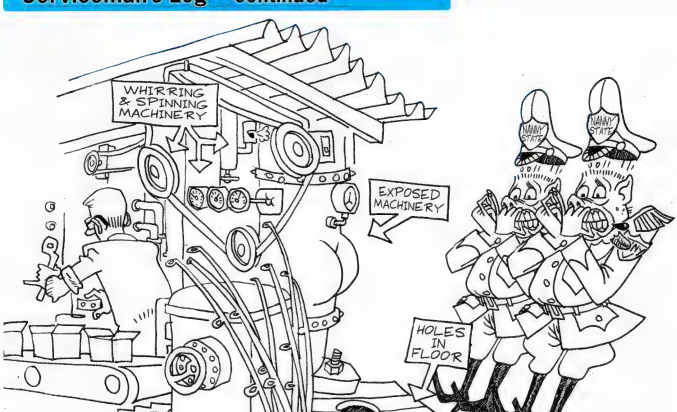
Mind you, manufacturers back then had a different philosophy as well, to make the best possible product and to make it last, even while making spare parts widely available should the worst happen. It made a lot of sense for owners to repair rather than replace, and while that meant the cost of buying new was dollar for dollar more prohibitive than it is today, products lasted much longer.

This all meant that Dad had an almost never-ending stream of jobs across his workbench and it was always littered with a variety of gadgets and the specialised tools he sometimes made to fix them. The nanny-state's health and safety police of today would likely have a fit if they could have seen this workshop, with the holes in the floor, exposed whirring and spinning machinery and the constant smell of hot fibreglass resin but I loved it and recall being very sad when Dad moved on from that venture to something else.

Fast-forward ten years, and his workshop was then almost exclusively electronics. This was during the CB-radio craze of the mid-seventies and Dad was manufacturing a CB radio called the Telstat Minicom.

My interest in electronics was getting more serious and this workshop was like a little slice of heaven for me. Given it was only a few kilometres from home, I ran there every day after school under the guise of "training" for athletics but my motives were ulterior. I would spend an hour or so with Dad and his then business

I RAN THERE EVERY DAY AFTER SCHOOL
UNDER THE GUISE OF "TRAINING" FOR ATHLETICS



~THE NANNY STATE'S HEALTH & SAFETY POLICE OF TODAY WOULD HAVE A FIT IF THEY COULD'VE SEEN THIS WORKSHOP

partner, sometimes helping stuffing circuit boards, punching holes in chassis or simply watching and learning.

Sadly, once the CB fad wound down, so did that business and Dad moved on to a home-based business, which meant his home workshop, which was already quite well appointed, gained some new specialised machinery and tools such as rotational moulders and vacuum formers.

Eventually, I picked up that mantle of the local repair guy and I'm still asked to repair home stereos or old radios and the like, mainly because the particular device holds sentimental value.

However, dare I say it, I think the art of repair is disappearing, thanks to this replacement culture, and manufacturers have a lot to do with it, with many changing their manufacturing methodology to reflect that culture. These days, even if the owner wants something repaired, it often can't be, due to the non-availability of spare parts. Just the other day I had to break the news to a neighbour that their 1992-era, 3-CD player cannot be repaired because I just can't find any suitable parts for it. Such is "progress" in the modern age.

Another example of this "no repair" culture is illustrated in something that happened to me recently. It is non-electronic but the situation has many parallels in the field as well.

A few months ago, I purchased a name-brand, 2-in-1 pneumatic stapler and brad nail gun from a large Australian-based hardware emporium who have several stores here in Christchurch.

This tool cost $99, which I thought a sensible price for a quality tool made by a well-known tool manufacturer. I especially like the bright-green plastic fittings, a trademark colour scheme this company uses on all their tools. The nail gun came with 250 18 gauge staples and 250 18-gauge brad nails and I bought it specifically to tack building paper onto the walls while renovating my latest workshop.

With this pneumatic staple gun, the job went very well, however even before I'd used up all the staples that came with it, the hard-plastic 'bumper' that clips onto the end of the barrel of the stapler broke in two and fell off the gun. This plastic piece offers some protection to the surface of the material you are stapling or nailing and assists in spreading the pressure applied when you push against the work, which you must do in order to activate the trigger mechanism and fire in the staple.

Without the plastic bumper on there, the end is quite small and being metal, easily marks timber or other softer surfaces. Indeed, when I tried

it without the bumper, the bared end tore the building paper on two out of five staple attempts, meaning I could no longer use it for this job.

I consider myself reasonably good with tools, that is, I don't habitually thrash them or put them under any more duress than they are designed for.

This is the line I took as part of an explanation email to the support and spare parts departments of this company in an effort to obtain a replacement plastic bumper.

Surely I couldn't be the first one this had happened to? I thought that this must happen often enough to warrant a healthy store of spare bumpers, made available through the retailer or website parts department. But no, the bumpers aren't available as a spare part.

I had to email back to make sure. Did no one else ever have this happen? I mean, the tip is plastic and takes a lot of hammering and once broken, the tool is a lot less functional, especially on surfaces we don't want marked. I'd pretty much have to junk the tool if I couldn't find an alternative solution. Then again, I shouldn't have to do that at all...

The first thing I did is what any self-respecting serviceman would do; I tried to repair it. After cleaning the two plastic pieces with isopropyl alcohol to remove any oils and grease, I applied a liberal amount of 24-hour epoxy resin and taped the cover together.

I left it for two days to be sure the epoxy had completely set. It lasted all of ten staples before falling apart along the same fault line. Disappointed but undeterred, I went to the same local hardware emporium and bought the strongest two-part glue I could find.

I also tasked the tool guys there about the bumper only to be told the same story.

This time I glued the piece in place, using a U-shaped piece of copper shim material formed to bridge the gap at the top and being careful not to get glue into any of the workings of the gun. To hold it all together, I added another layer of glue to the outside and wrapped the whole thing in a couple of layers of heavy-duty electrician's tape, pulling it as tightly as I could to squeeze the glue without breaking the tape.

As it dried, I periodically worked the staple mechanism to ensure it wasn't going to end up stuck together. After another 48 hours, I trimmed the tape back with a scalpel and carefully cleaned off any dried glue that would foul the end of the bumper. Since then, I've pumped at least 4,000 staples and brads of various sizes through the gun and it is still going strong.

However, the story didn't end there. After that initial email stating there was no such spare part, I wrote another email in response saying how disappointed I was that such a fragile and necessary part was not available and that the tool was virtually useless to me without it.

I said that I expected more from this particular company and considered it unfair that after paying over the odds for a better-quality tool, I actually ended up using it for less than a fraction of the time it should have lasted me. I told them I'd intended to use it for woodworking and joinery after the building paper job but that now looked to be out of the question.

It was about this time I decided to try and repair it, and since I ended up with a working nail gun, I considered it a win, no matter the company's response.

A few days later, I got a call from an Australian customer support representative. She asked for my postal address, which I gave, and she assured me the matter would be resolved. I thought they'd scraped up some bumpers after all and were sending them over, though it was a bit moot now I'd glued mine on.

However, that repair wouldn't last forever, so I'd at least have another bumper to replace it with. A few days later, a courier arrived with a large box, and I immediately thought this was a ridiculous amount of packaging for a couple of tiny plastic parts. Perhaps they sent a hundred of them!

When I opened the package, they had sent me a whole new nail gun! I'm extremely grateful for the amazing customer service but I can't help feeling they could simply make spare bumpers available and save themselves shelling out a lot of extra nail guns!

Medion computer repair

B. P., of Dundathu, Qld locked horns with a faulty Medion desktop computer. It was a time-consuming exercise but he eventually got it going again ...

I was recently given a Medion computer by a friend, after they bought a new computer. At the time, I was told that it no longer worked and that they would dump it if I didn't want it.

When I first saw it, I immediately noticed that the card reader door on the front panel was missing, as it had been accidentally broken off some time ago. However, the computer did have a Windows 7 license, making it a suitable candidate for repair, so I grabbed it.

When I got the computer home, I immediately decided to check to see what was wrong with it. I began by removing the side panel and unplugging all non-essential items from the motherboard. I then removed the RAM and cleaned the contacts before refitting it and turning the machine on.

It initially started up but then halted with a CMOS error. As a result, I got into the BIOS set-up, altered some of the settings and rebooted it. That didn't fix it, unfortunately. Instead, it was now completely dead.

All further attempts to get it working, including replacing the RAM with known good RAM, failed and it was now clear that the motherboard would have to be replaced. I then checked the hard drive on another computer. It was also dead, so something major must have happened to the computer to cause all these hardware failures.

Before going any further, I next decided to look into replacing the missing front-panel door. After all, there would be no point doing anything else to the computer with the front of it looking the way it was.

Much to my frustration though, the front panel proved difficult to remove, because the optical drive was blocking access to one of the retaining clips. However, by using a thin knife, I was able to pop the clip and then remove the panel.

I knew I had another Medion computer stashed in my shed and after some searching, I was able to locate it. This machine was considerably older than the one I wanted to repair and had a different front-panel layout. The case was also badly rusted at the back and the front power button was missing, so I didn't mind wrecking it for parts.

I removed the front panel from the older case, retrieved the door panel and door and compared it with the door panel from the newer case. It was significantly different, being some 6mm deeper than newer unit, so I completely dismantled the replacement door panel and trimmed it down to

Serviceman's Log – *continued*

size. I then reassembled it and fitted it to the newer panel.

This worked out well and in fact, the front of the computer looked completely original.

My next step was to see if I had a motherboard that could be used as a replacement. As it turned out, I had a very similar AMD-based motherboard that looked like a suitable candidate. This was a Gigabyte GA-880GM-USB3 Rev 3.1 motherboard with an Athlon II Quad Core 3.0GHz CPU, whereas the original motherboard contained an Athlon II dual-core 3.1GHz CPU. Provided I could get the replacement board working, it would have a bit more fire-power than the original unit.

I then rummaged through my box of DDR-3 RAM and managed to find four Kingston 2GB modules. I installed these in the replacement motherboard, fitted the board inside the case and ran Memtest 86+. It all passed with flying colours, so that was the RAM sorted.

I then cleaned and swapped over the original heatsink and fan from the faulty motherboard, as both were slightly larger than the stock AMD units on the replacement board. The fan was also fitted with a clip-on trumpet and this actually lined up better with the holes in the side panel than the original trumpet.

I also had a spare 500GB Seagate hard drive, so I installed that and then went about installing Windows 7 on the computer. Once finished, Windows 7 booted up without complaint and when I checked, I had 30 days left to activate it.

I then installed the drivers for the motherboard and the inbuilt WiFi card, which is located behind the front panel. After a few days of testing to make sure everything was OK, I then activated Windows so that the machine was now ready for use.

However, there was now a further problem. The original motherboard carried two internal USB 3.0 ports and there were two cables plugged into these: one running to a front-panel USB 3.0 socket and the other to a USB3 back-up drive connector on the top of the case. Unfortunately, these internal ports were lacking on the replacement motherboard.

I wanted to be able to use a USB 3.0 port on the front of the computer, so I had to think of some way of to connect it up (the back-up drive connector was less important). A search on eBay soon turned up a USB 3.0 PCI-e x1 card with two external rear USB 3.0 ports and an internal 19-pin header at the front of the card. This would be ideal, as I had already previously seen a 19-pin USB 3.0 plug to two USB 3.0 ports adaptor on eBay.

In the end, I ordered two adaptors and two cards and I waited for them to arrive. Once the parts arrived, I installed one of the cards and plugged in a 19-pin to two USB 3.0 ports adaptor and connected the two USB 3.0 cables. I then turned on the computer and grabbed the card's driver CD.

Unfortunately, finding the correct driver on the CD proved to be anything but straightforward. The CD contained several drivers, so it was a trial and error process until I found the correct one. Once that had been done, the two extra USB 3.0 ports were fully functional and ready for use.

Unfortunately, after about a week, the computer suddenly stopped working. I soon found that the replacement motherboard had failed completely, which was a real blow after all the work I'd put into it.

I had another look through my shed and this time I found an old rusty case with a Windows XP license. It also had a Gigabyte GA-880GM-USB3 motherboard, so I thought I would use this.

I then noticed that even though it was exactly the same model, this was a Rev1 board, whereas the one in the Medion was a Rev3.1 board. The main difference was a slightly different layout near the RAM slots, with the Rev1 board also having one IDE connector and one floppy drive connector, whereas the Rev3.1 board did not have these additional connectors.

Other than that, the two motherboards were almost identical, with the same number of SATA ports.

However, why do a simple swap when there's an opportunity to complicate things! I knew I had another Rev3.1 motherboard in another computer that I'd just upgraded, so I decided to remove it from that computer and use it in the Medion

The Rev1 motherboard could then be slotted into the donor computer. This would be a more practical arrangement because the donor computer had a moulded floppy drive slot in its front panel. By substituting the Rev1 motherboard, I could then connect the floppy drive again.

The motherboard swap went smoothly and both computers were soon back in operation again, each

Roberts DAB Radio Repair

Fixing a simple fault can sometimes involve a lot of disassembly work, as G. C. of North Ryde, NSW found out when he tackled a friend's DAB radio. There's always the risk of breaking something in the process.

I was recently asked by a friend to have a look at a 5-year old DAB radio which, after daily use in the bathroom, was refusing to switch on. The radio in question was a Roberts Ecologic 4 mains/battery set. Its owner said that it was a good performer and that he would like to have it fixed, if possible.

Working on modern electronic appliances is not my favourite pastime, as I much prefer restoring valve equipment. Despite this, I agreed to have a look at it as a favour owed.

Given that this is a digital set, my initial guess was that the fault was in the push-on/push-off power switch itself or with the associated logic. If it were the latter, then I was hoping the requisite part would be readily obtainable. Roberts is a British company, although the radio itself is clearly made in China.

Before spending time on the radio, I decided to Google the symptoms and found that this was a very common fault, with many disgruntled owners saying that the response from Roberts was to send the radio back to them for repair, along with the specified fee.

I couldn't find a service manual online so I emailed the Roberts Technical Department, requesting an explanation of the notoriously common fault to help me fast-track a local fix. They replied that I should send the radio to them for repair.

It was patently obvious I wasn't going to get any leg-up from the manufacturer.

At this stage, I decided to open up the set. This involved the usual routine of removing a dozen or so deeply-buried screws using a small-diameter, long-shafted screwdriver. The screws were of assorted gauges and lengths, so I made a note of which went where.

With the case split in half, I was confronted by a power supply board in the rear section, adjacent to the battery compartment, from which a number of wires ran across to two main PCBs: one for the radio function and its associated knobs and pushbuttons and the other for the stereo amplifier function.

These two boards are mounted back to back, with an insulating sheet sandwiched between them. This sheet consists of a piece of aluminium foil covered on both sides by black insulating material.

The upper PCB is made of fibreglass and contains mainly SMD components. By contrast, the lower PCB is phenolic and contains through-hole components. A plethora of wires run between these boards and to the stereo speakers. As well as those unpluggable cables, there were three wires soldered to metal inserts in the case which presumably provide shielding.

It's not what I'd call an elegant, optimised design by any means.

The on/off control is a 6 x 6mm pushbutton switch which is soldered to the upper PCB. Without further disassembly I was able to get my DMM across its terminals and confirm that it was functional, so the problem lay elsewhere.

Further Googling found just one technical reference to the fault and it laid the blame on a 4013 dual-D flipflop. That made sense, given that a momentary on/off switch needs a memory of its last switched state. And a dual-D flipflop is a typical way to accomplish that.

A small dental mirror allowed me to see that there was a SOIC chip soldered adjacent to the power switch, so I proceeded to remove the PCB sandwich from the case, layer by layer. Removing the lower PCB and the insulating layer was comparatively easy.

continued next page

with its original CPU and RAM. However, I did have to reinstall the USB 3.0 driver in the donor computer, because the Rev1 motherboard has a different USB 3.0 chip. Apart from that, all the other drivers for both motherboards were identical and there were no complaints from Windows about the motherboards being changed.

Although this had all been a somewhat time-consuming exercise, the end result is a refurbished, reasonably-modern computer that would have otherwise gone to scrap.

It may not be up to gaming but it's perfectly adequate for internet browsing, emailing and other similar activities. And because I got it for nothing and I used mainly recycled components for the refurbishment, it cost me much less than the price of a new computer.

Nothing to RAV on about

B. C. of Dungog, NSW recently turned auto-electrician when he took on an aging Toyota RAV4 with speedo, tacho and air-conditioning faults.

A friend's daughter has owned the Toyota RAV4 (a late 1996 model) for a number of years now. Unfortunately, due to its age (20 years) and high mileage, various problems have needed attention in recent times.

Recently, I was asked if I would look at problems with the speedometer, tachometer and the air-conditioning/heating system. And so, on a recent visit to her parent's place, I took the opportunity to examine the vehicle.

By this time, the speedo had completely failed and she was using the GPS function on a smart-phone to monitor the road speed!

Fortunately, the Nippon Denso instrument panel is relatively easy to remove from this vehicle. I then retreated with the faulty unit to my workshop,

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.

Serviceman's Log – *continued*

However, removing the upper PCB involved detaching the fascia from the case in order to reach three screws hidden underneath it. Unclipping the fascia without breaking it was a real chore but I was eventually able to reach the PCB.

A quick check with a DMM revealed a short between pins 7 & 14 of the 4013. Fortunately, it's a fairly common chip costing around 50 cents and a mate with an SMD reflow station kindly replaced it for me in a 60-second manoeuvre.

With the new chip installed, I reconnected everything on the bench, applied power to the system and pressed the power switch. Bingo! – the LCD displayed "ABC Radio connecting . . ." and a second or two later, sound came through the speakers.

As I reinstalled the PCBs inside the case and wrestled once again with the fascia, I began thinking that this hadn't been too painful a job after all. And then it happened!

The on/off button itself was attached to the upper part of the case by a flimsy web of plastic, about 1mm across, which acted as a sort of spring.

As the switch's own button was only about 2mm high, the on/off button activated it by way of an integral plastic shaft about 15mm long.

Unfortunately, as I attempted to line the button up with the switch, while simultaneously keeping the fascia in place, both the plastic web and the shaft disintegrated. There was nothing left to salvage or glue. Not happy, Jan!

After the customary string of choice words, I thought about my options. As there was little chance of reconstructing the original plastic shaft and spring arrangement, I decided to fit a new tactile switch with its own long shaft.

Fortunately, I was able to source one with a 17mm-long shaft (or actuator) and that was long enough to poke up through the hole where the on/off button resides. And so, once again, I had to remove the PCBs in order to solder in the replacement switch.

The next task was to gently ream out the button itself and fill the inside with Knead-It, a fast-setting epoxy putty. Once it had set, I then used a slow drill to make an indentation into the putty just deep enough to accommodate the top of the switch's shaft, while ensuring that the on/off button was at the correct height to remain in place in its hole.

I then proceeded to once again wrestle with the fascia and this time it all went together without any drama.

The new switch has a more positive feel about it, and my friend was very happy to have the radio back in working order.

placed it face-down on a towel and removed the speedo and tacho heads from the main PCB assembly. Each head in turn had a small PCB soldered to its rear containing a meter movement with two coils.

The speedo head (PCB – 0680) carried a 24-pin ND SE236 DIL IC but that wasn't the cause of the problem. Instead, there was a dry solder joint on one of the four coil pins (two pins per coil). The same problem was evident on the tachometer head PCB. This board carried a 16-pin D056956-0240 DIL IC and it too had a bad solder joint on one of its four coil pins!

Since these failures were due to vibration, I decided to blanket solder all the joints on both the speedo and tacho PCBs to ensure future reliability. It was then just a matter of reassembling the instrument panel, taking it back to my friend's house and refitting it to the vehicle. A subsequent road test then showed that both the speedo and tacho now worked perfectly.

It was now time to troubleshoot the air conditioning/heating system! Switching the fan speed to each position (with the ignition turned on), revealed that the blower fan motor wasn't running at all.

Removing the glove box and some trim items gave access to a subcontrol panel and the blower fan motor assembly.

A quick check with a DMM then indicated that +12V was present at the blower fan input connector, so it wasn't a supply problem.

I unplugged the unit and connected a 12V 7Ah gel battery directly to the motor input connector via some suitable test leads but there was still no response. As there were only three PK screws securing the blower motor assembly in place, it was easily dropped out for closer examination. Removing a small air vent cover then allowed access to the rear of the motor.

Close examination of the motor with the aid of a LED torch subsequently revealed that the brushes and commutator were both badly worn. And that meant that a replacement blower motor assembly would have to be obtained and fitted.

A search on eBay uncovered two locally-available secondhand units, both at a reasonable price. One of these was ordered and I bench-tested it before fitting it to the RAV4 during my next visit. This replacement unit completely restored the vehicle's air-conditioning and heating system to normal operation. SC

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FROM $269

12V AGM DEEP CYCLE BATTERIES

Quality batteries for deep cycle applications. The absorbent glass mat embedded in the structure of the plates reinforces the lead frame of each plate, and stops the plates from buckling under heavy discharge current.

75AH: 260(L) x 168(W) x 211(H)mm, 20.7kg SB-1680 **$269**

100AH: 330(L) x 172(W) x 217(H)mm, 28.4kg SB-1682 **$329**

WATERPROOF AND DUST PROOF XLR PP-1014

An IP67 waterproof XLR plate with cover, suitable for harsh environments. Great for use with PA gear and cabling that are used in outdoor conditions.

NEW

$7.95

NEW

$24.95

4 WAY USB POWERBOARD MS-4067

Up to 2,000mA total charging current can be shared between the 4 ports. Features a LED indicator, over current and short circuit protection. Includes a mains power adaptor.

15A MAINS CONNECTORS

15A sockets and plugs with large earth pin. Flexible clear PVC cover for screw terminal visibility. Suits 10mm dia cable. External cord grip and suction boot with IP20 ingress rating.

SOCKET PS-4004 **$8.95**

PLUG PP-4006 **$4.95**

NEW

FROM $4.95

VISIT OUR BRAND NEW STORE IN ALTONA VICTORIA

ARDUINO® COMPATIBLE DISPLAYS & ACCESSORIES

TECH TIP

DISPLAYS FOR ARDUINO®

One of the most useful things a device can do is communicate information to us. If our smartphone didn't have a screen it wouldn't be very useful. Arduino® is much the same, with most projects requiring some information to be communicated - about the sensors they are reading, or how they are doing at the little task we have set them to. Here's a guide to the many different displays that make up the Arduino® range, with some tips on choosing the best one for your application. We also refer you to projects where we have used them. Whether it be presenting basic numerical data, or even a complex graphical colourful display, there is a screen to suit your project.

RED 8 X 8 LED DOT MATRIX MODULE XC-4499

Could be used to show one or 2 digits or perhaps a small graphic. Can be daisy-chained for larger displays without using more pins. Display area is 32mm x 32mm. Uses 3 pins for data plus 2 for power.

www.jaycar.com.au/diy-christmas-star

$7.95

7-SEGMENT MODULE XC-4569

Most useful for numbers, but could be used to show some letters or small animations. Display area is 28mm x 10mm. Only uses 2 pins for data plus 2 for power.

www.jaycar.com.au/diy-arduino-breathalyser

$11.95

NEW

$14.95

RGB 128 X 128 LCD SCREEN MODULE XC-4629

Good for small but detailed text and graphical displays, similar to what might be found in a smartwatch. Controllable backlight. Display area is 26mm x 26mm. Uses 5 pins for data plus 2 for power.

$19.95

2 X 16 LCD CONTROLLER SHIELD XC-4454

Monochrome text display with controllable backlight and 5 input buttons (up to 8 custom characters). Display area is 64mm x 16mm. Uses 6 pins for display and 2 for power, 1 for backlight and 1 analog pin for key input.

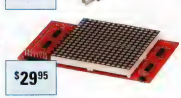
www.jaycar.com.au/diy-arduino-clock-uno

$19.95

84 X 48 DOT MATRIX LCD DISPLAY MODULE XC-4616

Monochrome 84x48 pixel graphical LCD with controllable backlight. Ideal for battery powered applications. Can show up to 6 lines of text or any combination of graphics. Display area is 32mm x 22mm. Uses 5 pins for data, 2 for power and 1 for backlight.

www.jaycar.com.au/diy-arduino-wifi-scanner



$29.95

16 X 16 LED DOT MATRIX MODULE XC-4607

Good for a small numeric readout or a small graphic. Can be daisy-chained for larger displays without using more pins. Display area is 64mm x 64mm. Uses 8 pins for data plus 2 for power.

www.jaycar.com.au/sudio-matrix-spectrum

$29.95

RED LED DOT MATRIX DISPLAY XC-4621

High enough resolution to display some letters or graphics. Daisy-chain for larger displays without using more pins. Display area is 320mm x 160mm. Ideally suited for marquee type applications. Uses 6 pins for data plus 2 for power.

www.jaycar.com.au/diy-arduino-clock

NEW

$29.95

RGB 240 X 320 LCD TOUCH SCREEN SHIELD XC-4630

Best suited for displaying graphics from a microSD card or detailed graphical and text displays, or small handheld games. Display area is 98mm x 44mm. Uses 13 pins for display and 4 for microSD card slot plus 2 pins for power.

www.jaycar.com.au/wireless-garden-monitor

$29.95

128 X 64 DOT MATRIX LCD DISPLAY MODULE XC-4617

Monochrome. Show 4 rows of 16 characters in text mode. Bright but compact display suitable for the desk or the car. Display area 71mm x 37mm. Can be run from just 3 Arduino® pins in serial mode, plus 2 for power and 1 for LED if you need to control it.

www.jaycar.com.au/christmas-clock

$159

INTELLIGENT 1.3" ROUND LCD MODULE XC-4284

Ideally suited for graphical gauges, needle-meters and robotics projects. Can play audio straight from the microSD card which is included. Display area has 35mm diameter. Uses 3 pins for data and 2 for power (includes Arduino® shield to 5 pin adaptor).

3D PRINTER ACCESSORIES

NEW

$19.95

CONDUCTIVE PLA FILAMENT 1.75MM 250G TL-4142

Conducts electricity so you can print your own low-voltage circuits, although its relatively high resistance is not suited to power circuits and could be used for signal circuits, touch sensor. Prints in a solid matt black.

NEW

$39.95

WAX FILAMENT FOR 3D PRINTER 1.75MM 250G TL-4140

Wax enables you to polish, machine or carve the printed object for desired results. Has a soft rubbery finish, and prints down to around 100 degrees. Could also be used to print models for lost wax casting.

$49.95

3D PRINTING TOOL KIT TD-2119

Handy tools to help keep your printer in top working order.

- 19 pieces in a carry case

NEW

NEW

$19.95

HEAT RESISTANT 3D PRINTING (KAPTON STYLE) TAPE NM-2817

Compatible with a wide temperature range from -269°C (-452°F) to 260°C (500°F). 50mm x 33m roll. Use on heated beds for better adhesion.

ARDUINO® SAVINGS

NOW $14.95

SAVE $10

SD CARD SHIELD XC-4552 WAS $24.95

It supports SD, SDHC, or MicroSD TF cards. Use the on-board toggle switch to select the SD card type.

- Operation Voltage: 3.3V
- 57.15(L) x 44.70(W) x 19.00(D)mm

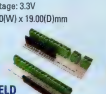
NOW $19.95

SAVE $10

LED MATRIX KIT XC-4592 WAS $29.95

This 8x8 LED Powered by MAX7219 and it only needs 3 data lines and 2 power lines. It has adjustable brightness. Usually used as electronic display panel.

- 52(L) x 34(W)mm



NOW $19.95

SAVE $10

SCREW SHIELD XC-4553 WAS $29.95

Extends all pins of the Arduino® out to 3.5mm pitch screw terminals. The screw terminal blocks allows sturdy, secure and dependable prototyping without the need for soldering.

NOW $24.95

SAVE $10

433MHZ RECEIVER SHIELD XC-4220 WAS $34.95

Lets you intercept 433MHz OOK/ASK signals, decoding them in software on your Arduino®.

- Reset button
- 433.92MHz tuned frequency

DUINOTECH PROJECT OF THE MONTH

ULTRASONIC PARKING ASSISTANT

Here is a great project to help you park your car in your garage. It simply uses an ultrasonic distance sensor to measure how far away the car is from the sensor, and then light up an RGB LED module to let you know how close you are. A simple job perfectly suited to an Arduino® project.

DIY

MORE INFO ONLINE

Finished project

XC-4410

XC-4442

WC-6028

XC-4428

SEE STEP-BY-STEP INSTRUCTIONS AT www.jaycar.com.au/ultrasonic-parking-assistant

WHAT YOU WILL NEED:

DUINOTECH CLASSIC (UNO)
XC-4410 **$29.95**

DUAL ULTRASONIC SENSOR MODULE
XC-4442 **$7.95**

150MM PLUG TO SOCKET JUMPER LEADS - 40 PCS
WC-6028 **$5.95**

ARDUINO® COMPATIBLE RGB LED MODULE
XC-4428 **$4.95**

VALUED AT $48.80

NERD PERKS CLUB OFFER
BUY ALL FOR $34.95
SAVE OVER $13

SEE OTHER PROJECTS AT www.jaycar.com.au/arduino

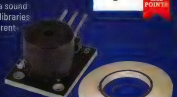
IMPROVE YOUR PROJECT!

ARDUINO® COMPATIBLE ACTIVE BUZZER MODULE XC-4424

Use this module to generate a sound warning from your Arduino®, libraries are available to produce different tones and frequencies.

- Operating voltage 5VDC
- Active speaker
- 3 pin header
- 25(L) x 15(W) 10(H)mm

$3.95 NERD PERKS 2x POINTS



DOUBLE-SIDED MOUNTING TAPE - 10M NM-2823

Mount your parking assistant to the wall. Thousands of uses, from mounting PCBs in your project to putting up your posters. Double-sided, foam backed.

$4.95 NERD PERKS 2x POINTS

$24.95 NERD PERKS 2x POINTS

SWITCHMODE MAINS ADAPTOR 12VDC 1.5A MP-3486

Power the parking assistant. Regulated output voltage, small size and higher power output make this AC adaptor suitable for thousands of different applications.

MODULE LEARNING KIT FOR ARDUINO®

XC-4286

Contains a duinotech MEGA, a breadboard, jumper wires and a plethora of peripherals in a plastic organiser.

See website for full contents.

$109

FREE TTL LEVEL SHIFTER SHIELD FOR ARDUINO® FOR NERD PERKS CARD HOLDERS
Valid with purchase of XC-4286
XC-4599 VALUED AT $5.95

PRACTICAL ARDUINO® BOOK BM-7132

Provides detailed instructions for building a wide range of Arduino® compatible projects covering areas such as hobbies, automotive, communications, home automation, and instrumentation. Soft cover, 422 pages.

NERD PERKS
RRP $54.95
$49.95
SAVE $5

ARDUINO® COMPATIBLE BREADBOARDS PB-8817

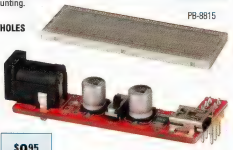
Breadboards for Arduino® and other DIY electronic projects. These have self adhesive tape on the back for easy mounting or screws can be purchased for permanent mounting.

170 TIE POINTS PB-8817 **$4.95**

830 TIE POINTS WITH POWER DISTRIBUTION HOLES PB-8815 **$14.95**

FROM $4.95

PB-8815



ARDUINO® COMPATIBLE BREADBOARD POWER MODULE

XC-4606

Receiving power from a USB socket or DC socket, this module adds a compact power supply to your breadboard.

- Plugs straight into most breadboards
- Can be set to 3.3V or 5V
- Concave design saves space

$9.95

WORKBENCH TOOLS FOR YOUR DIY PROJECTS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

1. CAT III AUTOMOTIVE METER QM-1444
- Inductive pickup for RPM measurement
- Dwell angle
- Works with engines of 2 to 10 cylinders.
- 600V, 4000 count
- AC/DC voltages up to 600V
- AC/DC current up to 10A
- RPM x1, x10

2. LED HEADBAND MAGNIFIER QM-3511
- Fits over prescription or safety glasses
- Adjustable head strap
- 1.5x, 3x, 8.5x or 10x magnification
- Requires 2 x AAA batteries

3. 48W SOLDERING STATION TS-1564 **WAS $99.95**
- Lightweight with ceramic heating element
- Analogue temperature adjustment (150°-450°C)
- 240V
- 150(L) x 115(W) x 92(H)mm

4. HEAVY DUTY CRIMPER/ STRIPPER / CUTTER TH-1827 **WAS $29.95**
- Strip all types of cable from AWG 10-24 gauge (0.13 -6.0mm).
- Crimps insulated & non-insulated terminals (1.5 - 6mm)
- Crimps auto ignition terminals (7-8mm)

5. STORAGE CASE HB-6302 **$24.95 EA**
- 4 trays: 233 x 122 x 32mm
- 13 compartments
- Top tray has a generous 265 x 160 x 65 space
- 270(W) x 260(H) x 150(D)mm

6. LONG BIT SCREWDRIVER SET TD-2114
- Includes popular slotted, Phillips, Star and TRI bits
- 22 pieces

NON-CONTACT THERMOMETER
QM-7215

Safely measure temperature in hot, hazardous, or hard to reach places. 8:1 distance to spot ratio.

ALSO AVAILABLE:
NON-CONTACT THERMOMETER WITH DUAL LASER TARGETING QM-7221 **$139**

$59.95

INSPECTION CAMERA QC-8710 $149

Excellent for inspecting or locating objects in tight spaces e.g behind wall cavities or in engine bays.
- 2.4" LCD. LED illuminated.

ALSO AVAILABLE:
2M EXTENSION LEAD FOR QC-8710 QC-8702 **$79.95**

BOTH FOR $199
SAVE $29.95

$14.95

AUTOMOTIVE CRIMP TOOL WITH CONNECTORS TH-1848

This excellent tool comes with 80 of the most popular automotive connectors. The tool will cut & strip wire, crimp connectors and also cut a range of metric bolts.

FREE AEROSOL BUTANE GAS 150G FOR NERD PERKS CARD HOLDERS*
*Valid with purchase of TS-1328
NA-1029 VALUED AT $5.95

PORTASOL GAS SOLDERING IRON TOOL KIT TS-1328

$159

This kit contains a Portasol Super Pro Gas Soldering Iron, storage case, cleaning sponge and tray, 2.4mm and 4.8mm double flat tip, hot air blow, knife tip and air deflector.
- 120 minutes run time
- 10 seconds fill, and 30 seconds heat up
- Maximum 580°C tip temperature (max 1300°C for built-in blow torch)

$24.95 NERD PERKS 2x POINTS

180MM BULL NOSE PLIERS TH-1984

Professional tool and manufactured to the rigid German DIN standards for electrical safety & mechanical strength. They are for serious tradesmen who need a quality tool. These pliers will cut hard wire up to 1.6mm & soft (annealed copper, aluminium silver etc.) up to 4.0mm. GS approved.

$24.95 NERD PERKS 2x POINTS

FUJIYA 175MM SCREW REMOVING PLIERS TH-2330

Japanese quality tool, skilfully machined to ± superb finish. The serrated jaws are uniquely designed to securely grip screw heads and extract them from seemingly impossible situations such as corrosion or stripped heads.

$29.95 NERD PERKS 2x POINTS

FUJIYA 110MM PRECISION LONG NOSE PLIERS TH-2334

These are the perfect companion for our TH-2332 precision side cutters ($29.95) and are made to the same exacting specifications. They also feature sturdy box joint construction.
- Hardness rating 53-57

WIN A PAIR OF RECHARGEABLE CB RADIOS

QC-1027

SIMPLY SUBMIT A PHOTO OF THE JAYCAR TOOL YOU CAN'T LIVE WITHOUT AND YOU COULD WIN.

WORTH $109PR

win.jaycar.com/workbench

Competition closes 23rd Jan. See website for the T&Cs

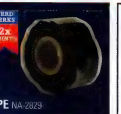
EXPAND YOUR TOOL BOX WITH THESE ESSENTIALS

SMART TEST SCREWDRIVER
TD-2655

$19.95 NERD PERKS 2x POINTS

- Capacitor/diode/ transistor check
- Globe/relay/fuse/speaker/resistor check
- Locating broken wire
- Instantaneously checks AC power
- Earth disconnection check
- Batteries included

SILICONE RESCUE TAPE NA-2829



Permenent air-tight and water-tight seal in emergency situations. Designed for quick plumbing repairs, sealing hoses, coating ends etc. Will repair a broken radiator hose (in most cases).

- 25mm x 3600mm

$11.95 NERD PERKS 2x POINTS

DIGITAL STEM THERMOMETER QM-7216

$29.95 NERD PERKS 2x POINTS

Multi-purpose, suits lab, factory workshop or barbeque. Features fast response, min/max memory and data hold.

- Non-corrosive stainless steel splash proof body
- Requires LR44 battery (included)
- 5000 hour battery life
- 205mm long

MINI NON-CONTACT IR IP67 THERMOMETER QM-7218

$34.95 NERD PERKS 2x POINTS

Ultra compact. LCD readout gives temperature in Celsius or Fahrenheit. Batteries and lanyard included.

- Measurement range: -33 - 110°C
- 82(L) x 17(Dia)mm

POCKET GAS TORCH TH-1610

It is a fully self-contained Butane 1300°C portable blow torch. It has simple press button Piezo ignition, flame control and safety lock. Has protective burner cap.

- 95(H) x 55(L) x 26(W)mm

$24.95

FREE AEROSOL BUTANE GAS 150G FOR NERD PERKS CARD HOLDERS*
*Valid with purchase of TH-1610 or TH-1606
NA-1020 VALUED AT $5.95

$44.95

MINI GAS SOLDERING TOOL SET TH-1606

Great for general workshop use. Features adjustment for temperature control, Piezo ignition, retractable stand, viable gas tank and child resistant latch.

$7.95 NERD PERKS 2x POINTS

LED WORKLIGHT

Powered by 3 x AAA batteries (included).

100 LUMENS ST-3270
WAS $9.95 NOW $7.95 SAVE $2

ALSO AVAILABLE:

180 LUMENS ST-3272
WAS $15.95 NOW $11.95 SAVE $4

250 LUMENS ST-3274
WAS $39.95 NOW $29.95 SAVE $10

$19.95 NERD PERKS 2x POINTS

COMPACT LED TORCH ST-3456

Massive light output of 190 lumens, a tactical switch and multiple light modes this torch is perfect for boating, camping or where your job requires it.

- 105(L) x 34(Dia)mm
- 3 x AAA batteries required

SAVE ON THESE OUTDOOR MUST HAVES

FIRE BLANKETS

Designed for extinguishing small fires. The fire retardant fibreglass fabric will suffocate the flame to restore safety. Keep one in your home, vehicle or at the campsite.

1M X 1M GG-2340
WAS $14.95 NOW $11.95 SAVE $3

1.2M X 1.8M GG-2342
WAS $24.95 NOW $19.95 SAVE $5

FROM $11.95 OVER 20% OFF

260 LUMEN LED HEAD TORCH WITH ADJUSTABLE BEAM

ST-3213 **WAS $19.95**

- High, low and strobe
- Wide to spot focus via zoom
- Comfortable head-strap
- 3 x AAA batteries required

SPECIAL $14.95 OVER 25% OFF

12VDC OSCILLATING FAN WITH CLAMP

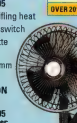
GH-1398 **WAS $24.95**

Keep cool in the stifling heat

- On/off oscillating switch
- Power via cigarette lighter socket
- 180(Dia.) x 145(D)mm

ALSO AVAILABLE:

FAN WITH SUCTION MOUNT BRACKET
GH-1399 **WAS $24.95 NOW $19.95 SAVE $5**



SPECIAL $19.95 OVER 20% OFF

RECHARGEABLE HANDHELD CB RADIOS DC-1009 WAS $79.95

- Sold as a pair.
- 0.5W, UHF, 80 channels
- With LED torch built in to it
- Charging cradle included
- Up to 3km range
- Up to 30 hours battery

SPECIAL $69.95 pr SAVE $10

80W OUTDOOR FLEXIBLE SOLAR POWER PACKAGE

Power and lighting for campsite or backyard shed.

BUNDLE DEAL INCLUDES:

80W SOLAR FLEXIBLE PANEL ZM-9153 **$329**
PORTABLE BATTERY BOX INCLUDES POWER ACCESORIES HB-8500 **$109**
12V 100AH DEEP CYCLE GEL BATTERY SB-1695 **$369**
FLEXIBLE LED STRIP LIGHT HOOK & LOOP CASE AND CARRY BAG ST-3950 **$99.95**

VALUED OVER $906

NERD PERKS CLUB OFFER
BUNDLE DEAL $849
SAVE OVER $57

TECH TIP

APPLICATION GUIDE FOR SEMI-FLEXIBLE SOLAR PANELS

They are an excellent option for boats, campervans, caravans or camping power or camping power setups, as they are a lot slimmer and less bulky than their standard solar panel equivalent. Their main structure is a sheet of aluminium alloy material that is flexible, allowing you to bend the panel slightly to follow the curves of your mounting surface for a slimline installation.

SLIM BALLAST XENON HID LIGHTS KITS

Provides far greater light output than standard automotive lights. All kits feature a slim ballast design for ease of installation in engine bays and tight spaces.

- 85(L) x 61(W) x 15(H)mm
- 300% more light than halogen

H4 SLIM BALLAST HID KIT 12V 6000K SL-3494 **$49.95**

H4 SLIM BALLAST HID HIGH/LOW KIT 12V 6000K SL-3495 **$84.95**

H7 SLIM BALLAST HID KIT 12V 6000K SL-3496 **$59.95**

Note: Please ensure your lights are angled correctly. These lights are not ADR approved.

FROM **$49.95**

FESTOON LED GLOBES CANBUS COMPATIBLE

A range of 150 lumens ultra-bright white LED replacement "festoon" globes for car interior lights. Fully compatible with modern "CANBus" systems. 120° wide beam. 12VDC.

31MM ZD-0750
36MM ZD-0752
41MM ZD-0754

$12.95 ea

12VDC INTERIOR LED RETROFIT KITS

Fantastic kits to upgrade your car/caravan/boat interior lighing to LED technology. Each kit consists of an array of cool white LEDs on a board with 3M® adhesive foam backing.

- Universal T10/211/BA9S

2.5W 260 LUMEN ZD-0585 **$8.95**
3.0W 310 LUMEN ZD-0587 **$12.95**
4.5W 450 LUMEN ZD-0589 **$14.95**

FROM **$9.95**

12V LED TRAILER LIGHTS KIT ZD-0722

LEDs last over 50,000 hours, use a fraction of the power, and are more visible to other road users. Sold as a pair. Kit includes 2x trailer lights, with a pre-made 7m trailer cable with 7pin flat trailer connector.

- ADR Approved
- Screw stud mount.
- 100(W) x 90(H)mm (each)

$69.95

BUNDLE **$439** SAVE OVER $35

4WD LIGHT BUNDLE

BUNDLE DEAL INCLUDES:

2 X 6,300 LUMENS 6.5" SOLID LED DRIVING LIGHTS SL-3920 **$199**

1 X WIRE STRIPPER TH-1824 **$16.95**

1 X UNIVERSAL RELAY WIRING KIT SY-4180 **$59.95**

Note: off-road use only

VALUED AT $474.90

FUSED CIGARETTE LIGHTER PLUG TO DC PLUG

$4.95 ea — NERD PERKS 2x POINTS

Internal fuse and LED power indicator. Supplied with 5A, 3AG fuse

- Cable lenght 1.5m

2.5MM PP-1997
2.1MM PP-2008

4-WAY POWER SPLITTER WITH USB PS-2019

$19.95 — NERD PERKS 2x POINTS

Power up to four 12VDC plug appliances at once (max 10A). USB socket (max 1A).

USB CHARGER WIRING KIT PS-2017

$22.95 — NERD PERKS 2x POINTS

Weatherproof cover, suitable for mounting on motorbikes, under-dash on boats or open-top cars. Outputs 5VDC to power or charge Smartphones, Tablets, GPS, etc. 12/24VDC. Supplied with 1.2m fused lead with SAE connectors for easy disconnects.

DUAL PORT USB CHARGER MP-3616

$24.95 — NERD PERKS 2x POINTS

Charge your USB devices in your vehicle. Supplied with mounting hardware. 1.0A + 2.1A USB ports, 3.1A max. output. 12/24VDC.

SINGLE CORE CONDUCTORS - 10M ROLLS

Tinned DC power cable suitable for general purpose automotive and marine applications. 15A rated current. Total diameter is 3.3mm. Max temperature 80°C.

RED WH-3054
BLACK WH-3055
GREEN WH-3056

$11.95 ea

TRAILER CABLES

A 10 metre length sheathed in a tough black PVC jacket. Makes wiring easy. See website for wiring guide.

5 CORE WH-3091 **$39.95**
7 CORE WH-3090 **$44.95**

FROM **$39.95**

FROM **$19.95**

NEGATIVE BUS BAR & BLADE FUSE HOLDER

These fuse blocks come with blown fuse indication LEDs. Transparent cover with recessed areas for label stickers.

MODULAR DESIGN NEGATIVE BUS BAR SZ-2011 **$19.95**

MODULAR DESIGN BLADE FUSE BLOCK SZ-2013 **$34.95**

$23.95

AUTOMOTIVE FUSE ASSORTMENT SF-2142

Contains 120 standard size automotive blade fuses in a 6 compartment storage box. Includes 20 each of 5A, 10A, 15A, 20A, 25A & 30A fuses.

ALSO AVAILABLE:

FUSE PULLING TOOL TH-1973 **$1.95**

$39.95 ea

HEAVY DUTY 12V CIRCUIT BREAKERS

High quality units with multi-wire gauge inputs/outputs, perfect for high powered car audio, automotive or solar installations.

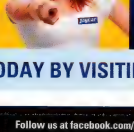
- Panel Mount

60A SZ-2081
120A SZ-2083
200A SZ-2085

NERD PERKS CLUB MEMBERS RECEIVE:

10% OFF

ALL DC POWER & TRAILER CABLES IN ROLL OR BY THE METRE



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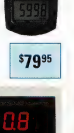

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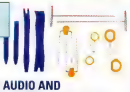

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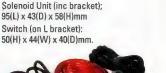

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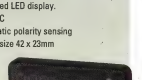

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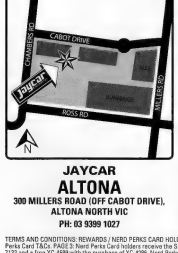

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. Those stores may not have stock of these items and can not order or transfer stock. Savings off Original RRP. Prices and special offers are valid from Catalogue Sale 26 December, 2016 - 22 January, 2017.

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

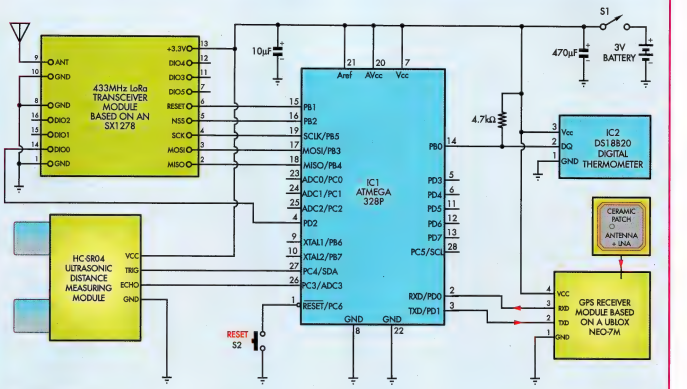

FIG.1: TRANSMITTER

LoRa remote repeater for ultra-long range digital communications

This project uses two different long-range digital radio modules with a repeater to transmit data to a remote location around 15km away, using standard 433MHz whip antennas.

The transmitter unit sends its GPS-derived latitude and longitude plus an ultrasonic distance measurement and local temperature using a 433MHz digital radio.

This is picked up by a repeater which then retransmits the data using a more powerful 433MHz transceiver for the second hop to a remote receiver which displays the data on an LCD. The repeater unit manages this process, as explained below.

An advantage of using a repeater, other than simply extending the range, is that it can allow communication between two points which do not have a line-of-sight, as long as they can both "see" a third point; possibly one which is at a much higher elevation to clear surrounding obstacles.

All four 433MHz transceiver modules used are based on the SX1278 chipset but the pair used for communication over the first hop (from transmitter to repeater) have 100mW transmit power while the second pair has 500mW transmit power and thus is capable of longer-distance communication. All three units are based around an Atmel ATmega328P processor and programmed with Arduino software.

At this point, we should mention that this unit was built and operated in India. In Australia, unlicensed 433MHz transmitters are not allowed to exceed 25mW (14dBm). So such a unit operated in Australia would not be capable of this sort of range. However, the transceivers can be programmed to operate at legal power levels (see below) and the overall principle is still sound.

Long distances may still be achievable, however more repeaters and higher-gain antennas would be required.

The transmitter circuit is shown in Fig.1. It runs from a single lithium-iron-phosphate cell of 3-3.7V.

Note that due to the lack of a regulator, lithium-ion and lithium-polymer cells are not suitable.

Microcontroller IC1, the u-blox GPS receiver, HC-SR04 distance sensor and temperature sensor IC2 are all powered directly from this cell, via power switch S1. Data is exchanged with the GPS receiver via an RS-232 bus using IC1's pins 2 & 3 (RXD and TXD).

Temperature is read from IC2 (a DS18B20 digital temperature sensor) using IC1's pin 14 (PB0) for Dallas

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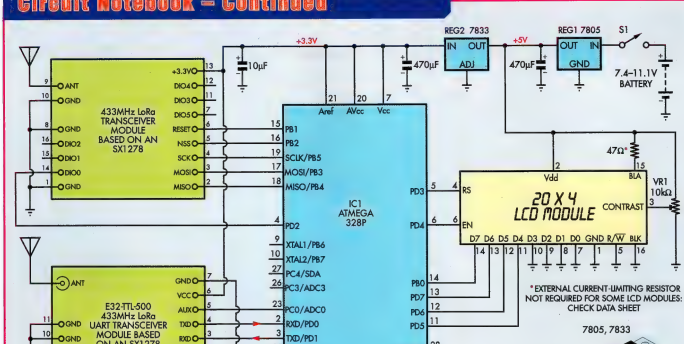


FIG.2: REPEATER

LoRa remote repeater . . .

1-Wire serial communication. The distance to a nearby object is measured using an HC-SR04 module with its trigger and echo lines connected to pins 27 (PC4) and 26 (PC3) of IC1 respectively.

An article on page 82 of the December issue of SILICON CHIP explains how this module works.

Microcontroller IC1 waits for a request for data from the repeater via its 433MHz transceiver, gathers the available data from the various sensors and then transmits a 32-byte burst using its SPI serial bus, on pins 17 (MOSI), 18 (MISO) and 19 (SCK).

Pin 15 controls the reset line on the LoRa module while pin 16 drives the SS (slave select) line. The transceiver is fitted with a 6dBi whip antenna.

The circuit for the repeater is shown in Fig.2. The connections for the transceiver shown at upper left are the same as those in Fig.1.

However, since this unit has an optional 16x4 alphanumeric LCD for displaying the data being relayed, it runs from a 3-cell lithium-ion or lithium-polymer battery of 7.4-11.1V.

This is reduced to 5V and 3.3V by REG1 and REG2. The 5V rail powers the LCD module, while the 3.3V rail powers everything else including the microcontroller and the transceivers.

Communication with the E32-TTL-500 transceiver is via the micro's serial port at pins 2 (RXD) and 3 (TXD). The three additional radio module control pins, AUX, M0 and M1 are connected to general-purpose I/O pins 23 (PC0), 24 (PC1) and 25 (PC2) respectively.

The software in this unit is quite simple: it sends a request packet via the upper transceiver and waits for a response. Assuming it arrives, it then decodes it, displays it on the LCD (if fitted) and then after a short (500ms) delay, re-transmits it via the other transceiver.

The receiver circuit is shown in Fig.3. This is similar to the repeater unit but the AUX, M0 and M1 pins of the E32-TTL-500 transceiver go to pins 15 (D9), 16 (D10) and 17 (D11) of IC1 and instead of the second transceiver, it features a relay with coil clamp diode D1 and driving transistor Q1, which is controlled from pin 23 of IC1 (PC0).

This relay can be used, for example, to power a siren in case the received data is outside the required parameters or in case no data has been received for a while.

The software for the receiver unit is similarly simple. All it has to do is wait for data from the repeater and then display it on the LCD. The current version of the software does not drive RLY1 but it would be simple to add some code to check the received data and switch the relay on under certain conditions.

The major components are available from the following sources:

- SPI 100mW LoRa transceivers (transmitter, repeater): www.siliconchip.com.au/l/aaae
- RS-232 500mW LoRa transceivers (repeater, receiver): www.siliconchip.com.au/l/aaad
- 433MHz high-gain whip antennas with SMA sockets: www.siliconchip.com.au/l/aaaf
- matching SMA connectors: www.siliconchip.com.au/l/aaag
- Arduino Uno clone (all three units): various Ali Express and eBay sellers.
- DS18B20 waterproof digital temperature sensor (transmitter): www.siliconchip.com.au/Shop/7/3359
- Ultrasonic distance sensor: www.

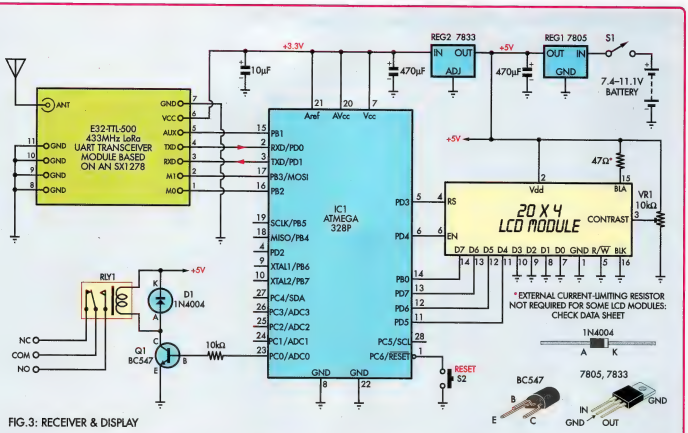


FIG.3: RECEIVER & DISPLAY

siliconchip.com.au/Shop/7/3338

The Arduino sketches for this project are available for download from the SILICON CHIP website (www.siliconchip.com.au) in a file named *Arduino_LoRa_Repeater.zip*; free for subscribers.

This includes the Arduino libraries required to compile the sketches: "*RadioHead*", "*TinyGPS-13*", "*NewPing_v1.8*", "*OneWire*" and "*DallasTemperature*". Each is supplied in a separate ZIP file within the downloaded ZIP and can be installed in the Arduino IDE via the Sketch → Include Library → Add .ZIP Library menu option.

Before uploading the software to the Arduino, be sure to modify the transceiver operating power levels to legal levels for your local area. For example, in Australia, you would add a line like:

driver.setTxPower(14, true); // set transmitter to 14dBm (25mW) maximum

This would need to be inserted in the setup() function for both the transmitter and repeater units.

Somnath Bera,
Vindhyanagar, India. ($60)

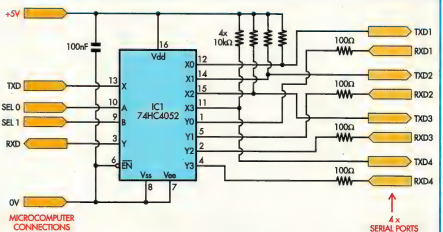
Two serial multiplexers

These two circuits expand the utility of two different kinds of serial ports and are primarily intended to interface with a microcontroller.

The first circuit is a one-to-four multiplexer for RS-232 logic-level serial ports, allowing one RS-232 port to connect to up to four other ports.

The second circuit allows an RS-485 "master" to communicate with slaves arranged along multiple cables; in this case, up to six, although it could easily be altered to handle a different number.

Starting with the RS-232 multiplexer shown at right; this can solve the problem where you've run out of hardware serial ports on a microcontroller. It has been used successfully for many years in commercial equipment without any problems. It's based around a 74HC4052 CMOS dual one-to-four multiplexer, IC1.



The micro's TXD and RXD pins connect to the multiplier's X and Y

continued next page

analog common terminals (pins 13 and 3) while the micro also drives the A and B inputs at pins 10 and 9. Depending on the state of the A and B inputs, the TXD and RXD lines are connected to one of X0 & Y0 (A=0, B=0), X1 & Y1 (A=1, B=0), X2 & Y2 (A=0, B=1) or X3 & Y3 (A=1, B=1).

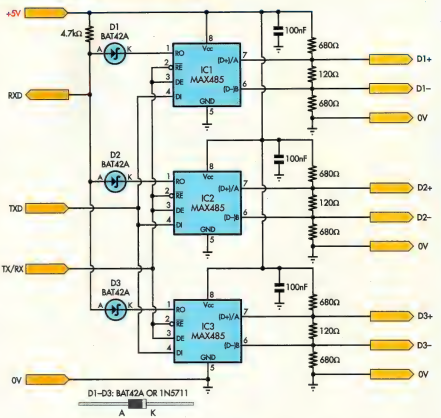
Since IC1 is an analog multiplexer, signals can travel both from the micro's TXD output, through the X terminal and out to the selected TXD1-4 line and back from the selected RXD1-4 line, through the Y terminal and on to the micro's RXD input.

Each TXD output has a 10kΩ pull-up resistor to the 5V rail so that it's held high when deselected, to prevent spurious transmissions (due to noise, etc). Each RXD input has a 100Ω series resistor to limit current from devices which may have a wider swing than 0–5V and for ESD protection.

This circuit could be expanded to handle more than four devices simply by adding more multiplexer ICs with the X and Y inputs connected in parallel and the A and B select lines connected to different outputs on the microcontroller. Also, if you need RS-232 voltage levels for communications with other devices, add one MAX238 or two MAX232s per 74HC4052 IC.

The second circuit at right allows an RS-485 master to interface with devices on multiple cables. Normally, an RS-485 master is connected close to the middle of a twisted pair cable and multiple RS-485 slave units are connected at various points along the cable, stretching away from the master in two directions.

However, you may have slaves running off in several different directions away from your master (eg, in a grid). This circuit allows more cables to be run, fanning out to four or six strings of slaves, or even more, if additional MAX485 ICs are used.



It works as follows. When the TX/RX line is driven high by the microcontroller, it can then transmit serial data to the TXD input. This connects to the DI (data input) pin of the three MAX485s (IC1, IC2 & IC3).

The $\overline{RE}$ input of each IC is high, disabling the RO (receive output) pins, while the DE pins (data enable) are also driven high, enabling the output drivers.

Thus, data from the TXD input is broadcast to the three differential output pairs, D1+/D1-, D2+/D2- and D3+/D3- and, presumably, received by the addressed slave on one of these cables.

When TX/RX is low, the output drivers are disabled (DE low) and the receivers are enabled ($\overline{RE}$ low). If data is sent by any slave, the RO pin (pin 1) of the corresponding interface IC is driven low and this then pulls the RXD line of the microcontroller low via one of diodes D1–D3, which effectively forms an AND gate in combination with the 4.7kΩ pull-up resistor to the +5V line.

This assumes that slaves will only transmit data upon prompting from the master and this will not "talk over" each other – an implementation detail left up to the reader.

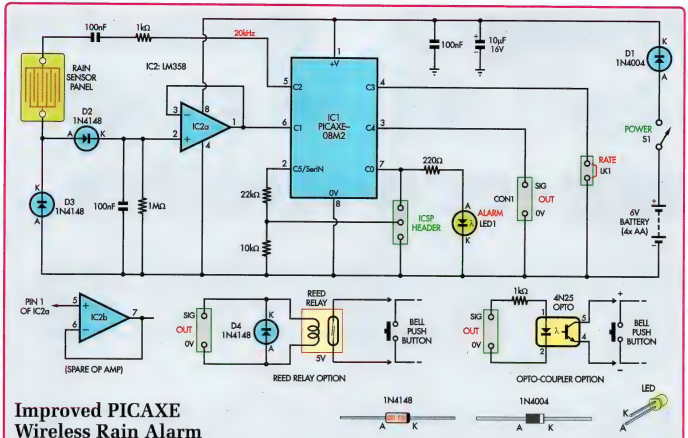
Each twisted pair cable should have a characteristic impedance of 120Ω and be terminated with a 120Ω resistor at each end.

Note that there is also a 120Ω resistor across the lines at the transmitter end, which provides a matching source impedance. The 680Ω pull-up (D+) and pull-down (D-) resistors should be fitted at the master end only, to set a defined state for the differential lines when no communication is occurring.

George Ramsay,
Holland Park, Qld. ($80)

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the Silicon Chip on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au



Improved PICAXE Wireless Rain Alarm

This circuit is a simplified version of my PICAXE Wireless Rain Alarm which was previously published in the Circuit Notebook section of the June 2016 issue. It can be used when hanging laundry out so that you are alerted as soon as it starts to rain and can bring it before it gets too wet.

The previous version used two PICAXE14Ms and a 433MHz wireless transmitter and receiver, while the new version uses a single PICAXE-E08M2 and a wireless doorbell.

The rain sensor consists of a set of interleaved tracks on a PCB. The resistance between the tracks reduces considerably when wet, triggering the alarm.

The rain sensor is driven with an AC voltage to prevent electrolytic corrosion. Rain sensor panels can be made of Veroboard or etched onto a PCB. The prototype sensor panel is 55mm square and uses a total of 20 closely spaced tracks.

Microcontroller IC1 generates a 20kHz square wave (AC) signal on output pin 5. This is coupled to the rain sensor panel via a 1kΩ resistor and 100nF capacitor.

The output of the rain sensor panel is then rectified by D2 and D3, filtered by a 100nF capacitor, buffered by op amp IC2a and the resulting voltage level feeds analog input pin 6 of IC1. The analog voltage level is low (near 0V) when the sensor panel is dry and several volts when wet.

The software monitors this analog voltage level and triggers an alarm when 2V is reached, producing a two-second positive pulse on output pin 3. At the same time, it pulses output pin 7 to flash LED1, which also flashes once at power-up.

Finally, the rate link (LK1) sets a delay of either 10 or 30 seconds between the alarm calls, allowing for each alarm (doorbell) tune to finish before the next starts.

To interface the unit with a wireless doorbell transmitter unit (button), use either a reed relay or 4N25 optocoupler (or equivalent), as shown at the bottom of the circuit.

The input side of either circuit fragment is connected across CON1 and the contacts/collector-emitter pins go across the pushbutton switch inside the wireless doorbell transmitter.

With the reed relay option, the polarity of the connection to this button is not important whereas the optocoupler collector must go to the positive side.

Most wireless doorbells are powered by three AA cells and have a 12V (23A) battery in the pushbutton (transmitter) unit. The absence of on/off switches means the batteries will need yearly replacement.

The sensor circuit shown here is powered by four AA cells and includes a power switch (S1) and series diode (D1). Switching S1 off extends the battery life and disables the alarm output signal. Diode D1 drops the battery voltage to just over 5V, to suit IC1, and provides reverse battery protection.

The circuit also includes an ICSP header to download software into microcontroller (IC1), with pin 2 as the serial input and pin 7 as serial output.

You will need a PICAXE-compatible USB cable to upload the "rain_alarm2_08m2.bas" BASIC program, which is available from the SILICON CHIP website. See **www.picaxe.com** for information on the microcontroller (IC1), including programming details.

Ian Robertson,
Engadine, NSW. ($60)

Using ARDUINO with the Atmel ATtiny85 Microcontroller

No doubt you have seen heaps of interesting applications for Arduino boards. But what if you want to use some of those ideas in a design of your own using the Atmel ATtiny85 microcontroller? It actually is quite easy and you can use Arduino software. Interested? Lawrence Billson takes up the story.

The ATtiny microcontrollers from Atmel are an ideal way to add simple programmable logic to your circuits. For example, the ATtiny85: it costs just a couple of dollars or so and with only eight pins it is an easy way to get started with adding a microcontroller to your own design.

And if you are not a software guru, the chip can be programmed using the free Arduino IDE (integrated development environment), making short work of simple electronics projects.

The ATtiny85 chip has five general purpose input-output (GPIO) pins. Three of them are capable of reading analog voltages while the other two are capable of "analog" output – more on that later.

Other than writing your program to the chip's built-in flash memory, all it really needs is a ground (0V) connection and a voltage of +2.7 to +5.5V on its V_{CC} pin (8).

With a few lines of code, the ATtiny85 can replace numerous analog or digital ICs and give your design the flexibility of being reprogrammable.

Although the Arduino IDE allows you to program in C (technically C++), knowing the language isn't critical. With the very large "community" built around the platform, many applications can be programmed using "cut and paste" methods.

Much of the Arduino code you find on the 'net will run on the ATtiny85 with little or no modification at all.

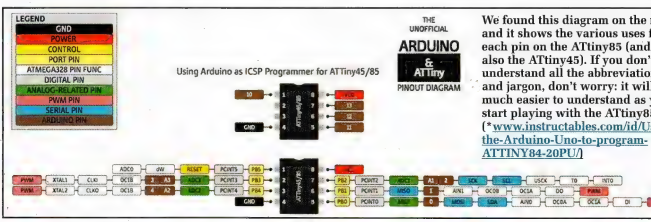
On paper, the ATtiny85 specs may seem underwhelming. It is an 8-bit micro with 8KB of rewritable flash memory for storing and executing your program, 512 bytes of EEPROM for storing things like configuration or calibration variables from your project and another whopping 512 bytes of RAM.

But don't let the meagre sounding specs fool you.

Using the freeware Arduino IDE, your code (or cut & paste effort) is transformed into tight, fast machine language using the built-in avr-gcc compiler.

In times gone past, a compiler for embedded processors was difficult to use and cost thousands of dollars – a huge barrier to entry. As well as being free, the Arduino software hides all of the 'engine room' parts like the compiler, chip 'fuses' and linker scripts.

Although the Arduino IDE is tailored for Arduino (or



We found this diagram on the net* and it shows the various uses for each pin on the ATtiny85 (and also the ATtiny45). If you don't understand all the abbreviations and jargon, don't worry: it will be much easier to understand as you start playing with the ATtiny85. (*www.instructables.com/id/Using-the-Arduino-Uno-to-program-ATTINY84-20PU/)

clone) boards, with only a few minor tweaks, it'll program your ATtiny chips nicely.

Development history

The ATtiny85 is based around Atmel's AVR architecture. This began life as a graduate project by two students from the University of Norway in 1996. They were looking to build a microcontroller that was based around flash memory.

Using flash memory allows a microcontroller's code to be changed without needing to expose chips to UV light or replace external ROMs.

Another advantage was that a product could be manufactured with a blank chip and programmed in the factory or field. If you pull apart many mass-produced products you may well find ICSP (In-Circuit Serial Programming) pads or pins on circuit boards for just this purpose.

Another problem the Norwegian students were attempting to solve was that of 'compiler bloat'. Chips like the Intel 8051, which was the dominant microcontroller at the time, use a complex instruction set (CISC) architecture.

While lending themselves to being programmed with assembly language, compiled languages would often become bloated as the compiler turned the program into machine language. This 'bloat' caused two problems: the code would become quite large and also quite slow to run.

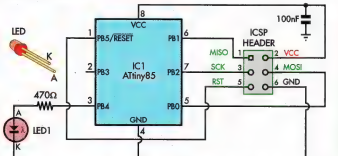
As the AVR architecture took shape, the students worked closely with the authors of a professional compiler named "IAR". Being developed in parallel, the AVR evolved to be very good for running high level compiled languages.

Classified as a RISC (reduced instruction set computer), it allows for most instructions to be executed in a single clock cycle and it hasn't changed much in the last 20 years.

Knowing that flash memory was a key component in their design, the students from Norway knew they would need to take their chip design to a company that had experience making flash memory. At the time there were two – one based in Japan and Atmel in the United States. The Norwegians decided they spoke better English than Japanese and therefore approached Atmel.

Since their release in 1997, Atmel have sold hundreds of millions of AVRs. They are among the most popular microcontrollers being used by industry. Earlier this year, rival company Microchip (makers of the successful PIC microcontrollers) struck a deal to buy Atmel.

While the ink on the contracts isn't yet dry and speculation is rife, it's highly likely they'll keep the AVR line for years to come.



SC ©2017 **YOUR FIRST ATTINY85 PROJECT**

Fig.1: one chip, one LED and one resistor – you can hardly go wrong! At right is the layout on a mini breadboard.

The ATtiny family is designed to be embedded into things. Tear apart a toaster or cordless drill and there's every chance you'll find one inside. They are available in DIP (through-hole) or a variety of surface-mount packages, and are equally at home on a breadboard or a mass-produced product.

In an interview on the excellent "embedded.fm" podcast, Atmel's Andreas Eieland talks about millions of their smaller chips finding their way into home pregnancy testers, of all things!

So what can you do with it? Controlling things like stepper motors and servos is easy, as is gathering data from temperature or humidity sensors. The ATtiny85 shines at smaller automation jobs. Instead of a 555 timer or some logic gates, I'll often grab an ATtiny85 for the same job. As a rule of thumb, if the application has only a couple of inputs and outputs, it might be a good choice.

If your application needs more pins or support for more complicated programs, the Micromite or larger AVR chips may be a better choice.

Getting started – what you'll need

You will need an AVR-specific ICSP programmer. Usually in the form of a USB attached gizmo, the ICSP allows the Arduino software on your computer to write its compiled program into the memory of your chip. The Freetronics unit will do the job well – see below.

As its name implies, the ICSP allows you to program your chip while it's in circuit.

But this is not really practical in the case of the ATtiny85 since most of the I/O pins are used by the ICSP and this will limit what you can connect to them. So it's best to program the chip on a breadboard before embedding it into your circuit.

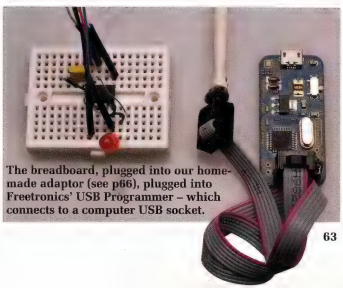
The 6-way connector that's standard on typical ICSPs isn't particularly breadboard-friendly either. So we will make up a simple 6-pin header as an adaptor to connect it to a breadboard.

You'll also need a computer (laptop or desktop) on which to write your programs – any PC that runs Windows, Linux of Mac OSX will be fine. The Arduino IDE can be freely downloaded from **arduino.cc**.

Other than that, you'll need some ATtiny85 chips and you're ready to get started.

Your first ATtiny85 project

We start with the simple circuit shown in Fig.1. It uses four of the ATtiny85's I/O pins to connect to the ICSP header



The breadboard, plugged into our home-made adaptor (see p66), plugged into Freetronics' USB Programmer – which connects to a computer USB socket.

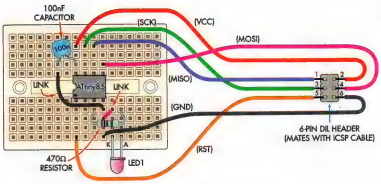
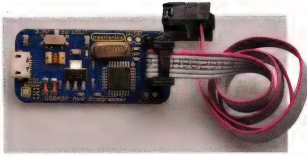


Fig.2: here's the breadboard layout for the Flashing LED project overleaf (Fig.1), along with the wiring for a 6-pin DIL header for programming.



Freetronics' $22 USB ICSP Programmer for AVR & Arduino. The six-pin socket on the end of the IDE cable mates with 6-pin ICSP header pin "plug" we shown you how to make later. This board then plugs into your PC via the micro-USB socket (left edge) and enables you to program the ATtiny85. (www.freetronics.com/usbasp).

socket and one of the remaining I/O pins to drive a LED.

The first program you will use will simply flash that LED and that's all. But you have to start somewhere. The circuit of Fig.1 needs to be made using a small breadboard and we have shown the component layout in Fig.2. So get your parts and a breadboard together. (*See "Using Breadboards" immediately following this feature*).

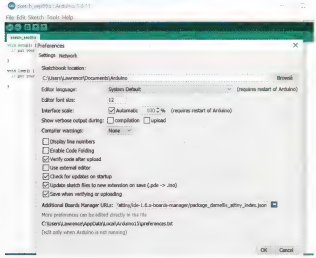
Note that you will need to solder six insulated wires to a 6-pin DIL header and that will provide the connection to the ICSP programmer. We also show a photo of the finished breadboard, ready to hook up to the ICSP and your PC.

Now you need to program the ATtiny85.

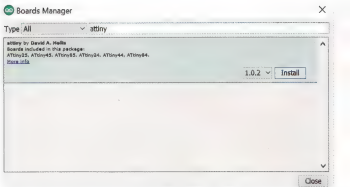
Begin by downloading and installing the latest release of the Arduino IDE. Be sure to say yes to installing all of the recommended drivers that are included with it.

The Arduino software comes ready to work with their officially branded boards. As we'll be using it to program ATtiny85 chip, we'll need to include support for it. You'll only need to do this once.

Once Arduino is installed, open the Preferences window and find the section for "Additional Boards Manager URLs" – paste in **https://raw.githubusercontent.com/damellis/ATtiny/ide-1.6.x-boards-manager/package_damellis_ATtiny_index.json** and click OK.



Under the "Tools" menu, select "Board:" , then click on "Boards Manager". Type ATtiny in the search box. Select the ATtiny library by David A. Mellis, and click 'Install'.

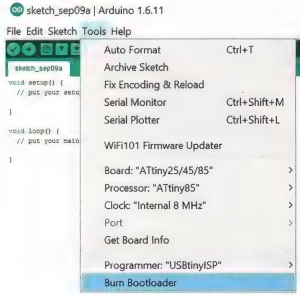


From now on, your Arduino IDE will know about the ATtiny85 chips and be ready to program them.

You'll need to tell Arduino about the chip we want to program. Under the "Tools" menu, select "Board <Name>" and you'll now see 'ATtiny' as an option. Select this. You must now go back in and give it some more details – in this example set:

Board - ATtiny
Processor - ATtiny85
Clock - 8MHz (internal)

Be sure to select the internal clock. If you accidentally



select an external clock your ATtiny85 can't be programmed unless you connect an external crystal.

Now we need to tell Arduino what type of ICSP we'll be using. For the Freetronics XC4237, select "USBasp".

Now you can go to "File", select "Examples", "Basics", and open "Blink".

The blink program normally tries to blink an LED connected to pin 13. But your ATtiny85 doesn't have quite that many! We have connected our LED to pin 4 (as in Fig.1), so you will need to change all of the references from "13" to "4".

MISO connects to MISO, MOSI connects to MOSI. Some programmers won't supply any power to the board so you may also need to connect up a power supply or batteries. Other programmers may have a jumper marked V_{OUT} which you can short, thus powering your board from the ICSP. Check with a multimeter to verify your V_{CC} line is between 2.5 and 5.5V.

For each new chip, you'll need to set its fuses. This tells the chip how to behave before it starts running any programs (eg, to use the 8MHz internal oscillator). Click on "Tools" then "Burn Bootloader". Keep an eye out for error messages.

If all has gone well so far, it's time to write your code to the chip Connect your ICSP programmer to the 6-pin header from the breadboard and connect the programmer to your PC.

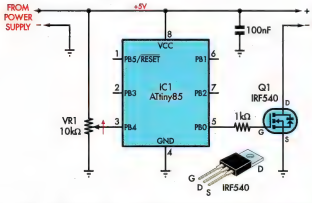
Holding down shift, click on the green arrow. This will compile your code and write it to the chip using the ICSP programmer.

If all has gone well, you'll have a blinking LED on your breadboard. Congratulations.

LED strobe

Our next circuit and program is for a simple LED strobe light. You have a wide choice of high-brightness LEDs of various colours for this job but I chose a Jansjo 2W LED lamp from Ikea. It comes with a handy plugpack power supply, to provide the LED with 4.5V DC.

Our ATtiny85 can modulate with an N-channel FET and the circuit is shown in Fig.3. Pin 4 of the ATtiny85 drives the gate of the Mosfet whereas in the previous circuit it just drove a LED via a 470Ω current-limiting resistor. The software is "Ikea_Strobe.ino".



ATtiny85 BASED STROBE LAMP

Fig.3: instead of flashing a LED directly, the strobe circuit drives a Mosfet which in turn drives a more powerful LED. VR1 varies the rate of the flashing LED.

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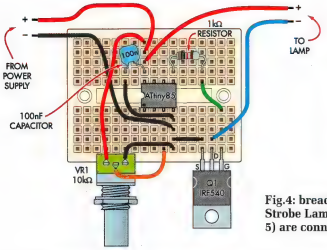


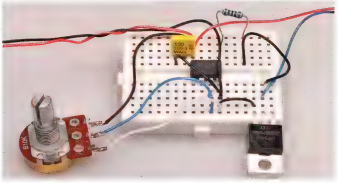


Fig.4: breadboard layout (along with a matching photo) for the ATtiny85 Strobe Lamp. Just remember that all of the north-south holes (in groups of 5) are connected inside the breadboard; all of the east-west holes are not.

But before you wire up the strobe circuit on a breadboard, as shown in Fig.4, you have to load the strobe software into the ATtiny85 using the breadboard layout of Fig.2.

In fact, we suggest you keep that Fig.2 breadboard as your dedicated ATtiny85 programmer.

Before uploading the strobe code, don't forget to "burn bootloader" to your new chip to set its fuses. Once the fuses are set, you can upload your code.

The strobe software task is divided into "start" and "loop" sections. When power is first applied to the micro, the start section is executed – this sets pin 0 as an output and pin 4 as an analog input.

The loop section is then executed. In this, the micro sets pin 0 high (switching on the Mosfet, allowing current to pass from the lamp to the power supply). The micro waits for 5ms and sets pin 0 low; turning off the lamp.

The micro then measures the voltage at the potentiometer wiper. Depending on the position of the potentiometer, the value measured will be between 0 and 1023. The micro then waits for that same number (ie, between 0 and 1023) of milliseconds, allowing the strobe to vary its 'off time'. As soon as this completes, the loop begins anew.

So having built the strobe breadboard of Fig.4, you can plug in your freshly programmed ATTtiny85 chip and you are ready to go.

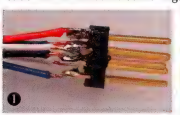
Audio Thermometer

This project makes use of the DS18B20 digital thermometer chip (or probe). Rather than displaying the temperature as a number, it plays a tone corresponding to the relative temperature it measures.

The DS18B20 is available in different package types – most commonly a TO-92 which looks just like a small transistor. It's also available in a waterproof probe suitable

How to make the 6-way ICSP connector

It's easy to make a connector for ICSP – all you need is a length of 2-way pin header (eg, Altronics P-5410) and carefully remove a 3-pin length. The wiring we used came from a length of 4-wire discarded telephone cable (yep, we never throw anything out!) It has colours of red & black (ideal for power) and blue & white (for everything else). You could also use female-male jumper leads and avoid some soldering.

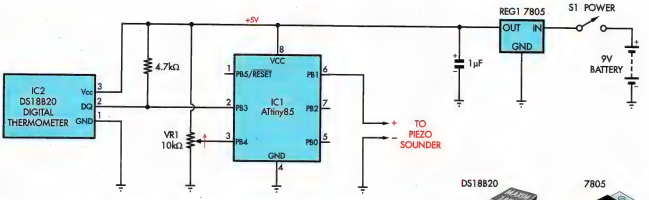


(1) Cut off a 3 x 2-way length of pin header and solder six wires to it. A red wire connects to the + terminal and a black to –; other colours can be what you have available.

(2) Apply a glob of hot melt glue (or silicone sealant if you don't have hot melt) over the soldered pins and back up the wires to keep the wires in position when it is being used. Allow to dry.

(3) Cover with a length of heatshrink tubing, right down onto the glue. This will stop it trying to pull apart as it is inserted and removed from the socket.

(4) Slide some short lengths of white heatshrink over each wire towards the plug, and some longer lengths of heatshrink over the opposite ends of each wire to make them stiffer. With a multimeter, identify which pin goes to which wire and write it on the white heatshrink. Shrink all heatshrink . . . and it's finished!



ATtiny85 BASED AUDIO THERMOMETER

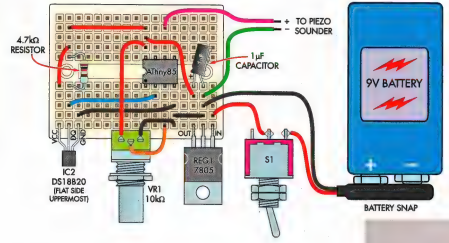


Fig.5 (above): the Thermometer uses a DS18B20, small solid-state digital thermometer chip, which will feed a number sequence to the ATtiny85 representing the temperature it is sensing. The ATtiny85 then generates a tone for the piezo sounder corresponding to the temperature.
Fig.6 (left): the breadboard layout for the audio thermometer. It's a little more complex so make sure the components and wire links, etc, are in the right place. You can also refer to the matching photograph (below).

for immersion into liquids up to about 120°C.

The circuit of the Audio Thermometer is shown in Fig.5 and the breadboard layout is Fig.6.

In this case we are using a 9V battery to power the circuit and this is reduced to 5V for the ATtiny85 and the DS18B20 thermometer.

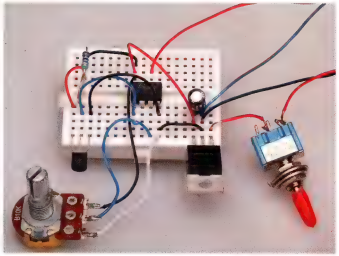
The data line from the DS18B20 is fed into the PB3 input, pin 3 and also pulled high with a 4.7kΩ resistor.

As with most Arduino programs, the Thermometer code is divided into the "Start" and "Loop" sections. An external library of functions is also loaded, to communicate with the DS18B20 thermometer. We simply tell the library which pin it's connected to, and request a temperature reading whenever we want.

The "Start" routine runs once as the chip is powered on. It initialises the DS18B20 and sets the PB1 pin (6) connected to the piezo to be an output. It also sets the pin connected to the potentiometer wiper as an analog input – this is used to vary the range of the tones.

The "Loop" function starts by requesting the temperature from the DS18B20. It then measures the analog value from the potentiometer wiper. The temperature value (reported in °C) can go as low as -55°C. As we'll be turning it into a frequency, we need to ensure it is a positive number. We do this by adding 60. We then multiply this number by the value of the pot to derive a frequency in Hertz.

The tinyTone function is then called to output this frequency to the piezo speaker for 600ms before the loop restarts. As its name implies, tinyTone is a function that



generates square wave tones. It does this by setting a pin high, waiting for a number of microseconds, then setting it low before waiting and repeating.

Want it to tell you the temperature in morse code? Want it to play different tones if the temperature is lower than 35.9° or above 36.7°C (armpit temperature)? With a little experimentation, either of these is quite simple.

As before, you will need to program the ATtiny85 with the breadboard of Fig.1 and then transfer it to the breadboard layout of Fig.6.

Next steps

Looking under the Examples in the file menu, you'll see some easy to follow examples. Because the ATtiny85

ATtiny85 pin functions

Digital: All of the I/O pins are capable of digital input and output. They can be set either high (VCC) or low (0V). They can also read a digital high or low as well.

Analog In: These pins are capable of reading a voltage of between 0 and your VCC voltage, providing a 10-bit number: 0V reads as "0" while VCC reads as "1023". If you need to measure higher voltages, you can use a voltage divider circuit to reduce the voltage going into this pin.

PWM: Pulse Width Modulation (PWM) output – these pins can simulate an analog voltage output by using PWM. Instead of adjusting the voltage, they can send shorter or longer pulses, thereby changing the average voltage. For applications like motors or lights this works well. You can set these pins to an 8-bit value (ie, 0 to 255). When set to a value of 0, the pin has a 0% duty cycle and is equivalent to 0V. At 255, it has 100% duty cycle and is equivalent to your VCC voltage.

ICSP Pins: Connect your ICSP to these pins to program your chip. MISO and MOSI stand for 'master in, slave out' and 'master out, slave in' respectively. SCK is the 'chip select' that tells the chip the programmer is talking to it.

Reset: This is normally held high (ie, at 5V or whatever VCC is) by the chip. When pulled briefly to ground, the chip resets and starts running its program again.

PINS ON THE ATTiny85

ICSP PINOUTS
(Top view, looking at a programmer)

You'll note the pin numbers in software don't correspond with the physical pin numbers of the chip. This diagram will help translate between the software world and the real world.

Parts you will need

First of all, you need the Freetronics ICSP Programmer for Arduino which you can buy on Freetronics' website (www.freetronics.com.au) for $22.00 plus shipping

See www.freetronics.com.au/blogs/news/8607215

It comes with a ribbon header cable (6-pin to 6-pin) and a short USB cable (type A to micro-B). And they'll throw in a mini protoboard for only $2.00 more – just what you need!

By the way, Freetronics also provide a PDF guide to using their Programmer, which readers may wish to use in conjunction with the description provided above.

Other main parts (Not a complete list... These components will allow you to build any one of the projects here but some components are common to all three).

- 1 Atmel ATtiny85 microcontroller (Altronics Z-5105)
- 1 DS18B20 digital thermometer chip (Altronics Z-7280)
- 1 IRF540N N-channel Mosfet (Altronics Z-1537; Jaycar ZT2466)
- 1 7805 5V regulator (Altronics Z-0505; Jaycar ZV1505)
- 1 red LED (Altronics Z-0700; Jaycar ZD0150)
- 1 Jansjo 2W LED lamp and 4.5V DC plugpack from Ikea
- 1 1µF 10V electrolytic capacitor
- 1 100nF polyester capacitor
- 1 470Ω resistor
- 1 1kΩ resistor
- 1 4.7kΩ resistor
- 1 10kΩ potentiometer
- 1 x 2 pin DIN plug (Jaycar PP0300)
- 1 x 2 pin DIN socket (Jaycar PS0340)
- 1 x 8 pin IC Socket (Jaycar PI6452)
- 6 300mm lengths single-core copper or tinned copper wire ("bell wire")
- 1 2x3-way DIL pin header (may to be cut down from larger – eg 2x10-way

(If not obtained above from Freetronics): 1 small breadboard (protoboard) (Altronics P-1020; Jaycar PB8817)

You can download the code (programs) required from www.siliconchip.com.au/

doesn't have many pins or built in peripherals (like SPI or I²C), some of those programs won't work but they can still give you many examples to copy to your code from.

Now is a good time to take a look at the Arduino community for other sources of inspiration and problem solving.

If you're having a problem with something, it's almost certain that you're not the first person to come across it and someone else will probably have solved it.

References:

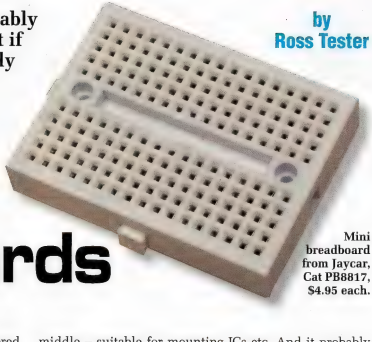
www.atmel.com/images/doc0943.pdf – shows how to use ICSP with other things connected to the pins. Embedded.fm episode 15

http://embedded.fm/www.instructables.com/id/Using-the-Arduino-Uno-to-program-ATTINY84-20PU/ – not the exact chip we're using here but gives a lot more information about programming the ATtiny series using Arduino. SC

If you're into electronics, you probably know – and use – breadboards. But if you're new to the game, these handy devices will make it a lot simpler! Here's a brief introduction.

by Ross Tester

Using Breadboards



Mini breadboard from Jaycar, Cat PB8817, $4.95 each.

These days, 99% of electronics projects are soldered onto PCBs, or Printed Circuit Boards. But for experimentation, circuit development and "proof of concept" (ie, does it work!), nothing beats a solder-less breadboard (sometimes called a prototyping board).

Every hobbyist and even professionals should have one or more of these in their arsenal! They're available in various sizes, depending on your particular applications.

However, it may be that you have never used one of these before so a few words of explanation now might save a few tears later!

What are they?

They're simply a way of mounting and connecting components, thus making it easier to work out what you're doing and at the same time, minimise the chances of components or connecting leads shorting to each other (with possible catastrophic results!).

The one thing they all have in common is rows and columns of holes, into which you can poke component leads. Depending on which holes you choose/use, they may connect to other components. The rest will require connecting leads, also known as jumpers leads (no, not the ones you use to get a car started!).

Some breadboards are supplied "as is"; others may have additional circuitry alongside to mate with a particular platform (such as Arduino).

Size

Breadboards are available in a range of sizes from the mini (about 40mm x 87mm and with 17 x 10 holes for a total of 170) right through to 157 x 273mm monsters with 2309 holes; some (like the photo shown opposite) are mounted on a backing plate which may have rubber feet plus provision for power, earth, etc via binding posts.

Some, like the mini type, are designed to clip into each other if you need a larger board. Others (especially the larger ones), are the opposite – they're designed to have their segments separated so the configuration can be changed.

And there are also variations in the board design – most feature a very obvious gap (or more than one) across the middle – suitable for mounting ICs etc. And it probably shouldn't surprise you to find that the spacing between the holes is 0.1 inch, the same as the pin spacing on ICs and many other components.

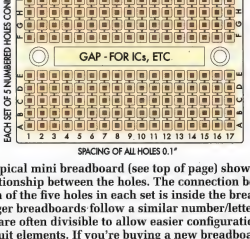
The holes

One thing that is universal to all breadboards is that under every hole is a pair of (usually) sprung brass connectors, so that any component or wire poked into that hole will connect to it.

Most "typical" wire component leads will fit into the breadboard holes; some larger components or components without wire leads will need to be connected by wires soldered to the component.

Hole identification

Another thing is almost universal: along all the edges are a series of numbers and letters, so you can identify a particular hole by reading the two values. These are often moulded into the plastic which makes them rather difficult to see, but they are there if you look closely!



A typical mini breadboard (see top of page) showing the relationship between the holes. The connection between each of the five holes in each set is inside the breadboard. Larger breadboards follow a similar number/letter scheme but are often divisible to allow easier configuration of circuit elements. If you're buying a new breadboard, you'd be better off buying a larger one than a small one.

This kit of handy insulated jumper leads is specifically made for breadboard use. 70 pieces in various lengths and colours are supplied with ends bared and bent at 90°. It's available from Jaycar Electronics for $13.50 (Cat PB8850). Altronics have a similar, though larger kit (350 pieces) for $32.50 (Cat P-1018).

For example, on the mini board shown above hole C9 would be on the third row up from the bottom and right in the middle horizontally.

On larger boards, the numbers are usually printed and easier to see (see opposite).

Columns of numbered holes are connected

Invariably, there are many columns of five holes, "numbered" for identification. Each of these five holes are connected to each other. So any component lead (or connecting wire) placed in these holes will be connected to other holes in the same row.

Larger breadboards have multiple groups of five holes

But rows of lettered holes are not!

In most cases, rows of "lettered" holes (eg, ABCD, etc) are NOT connected together, so you can mount a multi-leg component and connect it with jumpers, as explained below.

Bus bars

The exception to this is where is a line is printed on the board adjacent to the holes, especially (but not always) along the edges of the board (see above right).

It's normally red (for +) and blue (for –) and is to allow one or more convenient supplies or earth lines. Because there are usually multiple connections to power and earth, it's more convenient to have these "bus bars" run right along the edges – and sometimes down the middle and on top, as the Altronics deluxe breadboard shows.

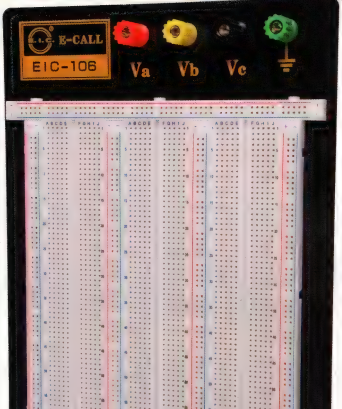
Connecting wires or "jumpers"

Connections between components are made with "jumpers". Where two close holes are to be connected, an appropriate length of component lead offcut is often used. However, this does not allow the jumpers to cross over each other unless at least one of the wires has insulation on it.

For longer cross-board connections, many breadboard kits are supplied with insulated jumpers for this purpose. If you run out, or if you don't have any with your breadboard, lengths of sturdy, insulated, single copper or tinned copper wire are used. This is sometimes known as bell wire – or can be cut from older 4-wire (single strand) cables of the type used for phone or alarm wiring.

Once the four colour-coded wires are stripped from the outer sheath, they're each cut to appropriate lengths and about 5-10mm of insulation is removed from each end.

Note that multi-strand wire is not very successful because



A deluxe 2309-hole breadboard mounted on a metal plate, complete with four terminals. Note the numbered columns and lettered rows plus the ten supply rail rows, marked by red and blue lines. Available from Altronics (Cat PP1015A; $47.95) www.altronics.com.au.

the strands tend to bend and separate as they're pushed into the holes. If you *must* use a multi-strand wire, lightly tinning the ends may help.

Low voltage only!

Note that breadboards can only be used with low-voltage circuits (say up to about 50V). Over this voltage they really aren't safe when there is so much exposed component wiring about. Maximum current would be 200mA or so.

And now for today's trivia!

Why are they called breadboards?

Way back in the "olden days", decades before the luxury of prototyping boards, experimenters used to assemble circuits with point-to-point wiring. The problem was, the components moved about, so they need a firm base onto which they could fasten things like valve holders; something they could screw into.

For this, a relatively large piece of softwood was the go . . . and where was the ideal candidate?

Of course! In the kitchen – Mum's breadboard! (But only if you could get away with it).

Much, much later a very clever bloke named Dick Smith used a very similar approach for the original "Fun Way into Electronics" projects. Except he advised constructors not to pinch mum's breadboard but use small scraps of timber instead! SC

PRODUCT SHOWCASE

Heavy duty Li-ion-powered soldering iron from ARI

Many's the time a tradie wishes for a powerful soldering iron away from power sources. Until now, that's usually meant a butane gas-powered iron . . . which runs out of gas at precisely the worst possible moment.

Now there is a powerful alternative, a tradesman-quality iron powered by a Lithium-ion battery.

Master Instruments is partnering with Aussie Rechargeable Irons (ARI) to market this innovative rechargeable battery powered cordless soldering iron. They are designed and built in Australia for tradies by tradies.

ARI have taken the old butane gas-powered soldering irons into the 21st century. No gas means no fuel, no flame, no combustion and no leaks. And they can be used in a windy environment which could "snuff out" gas irons.

A rugged 6061-grade powder-coated aluminium body means it can handle the rough stuff that tradies inflict on their tools.

With a copper-core element, the iron is ready to solder in less than seven seconds from turn-on. And the iron is hot enough to solder 10-gauge wire.

Using the best Japanese made Lithium-ion cells currently available and featuring integrated PCM protection, ARI's cordless soldering irons are high powered, fast heating and long lasting with up to one month's average use per charge. A range of interchangeable tips is available to suit all soldering applications.

And when it's time to recharge, that will only take 2-3 hours.

Contact:
Master Instruments
33-39 Sloane St, Marrickville NSW 2204
Tel: (02) 9519 1200
Web:www.master-instruments.com.au

New MCUs from Microchip feature CIP

Microchip Technology Inc has released a new generation of 8-bit tinyAVR MCUs, the first tinyAVR microcontrollers to feature Core Independent Peripherals (CIPs). The new devices will be supported by START, an innovative online tool for intuitive, graphical configuration of embedded software projects.

The new ATtiny817/816/814/417 devices feature a low pin count and feature-rich packaging with 4KB or 8KB of Flash memory, a CIP called Peripheral Touch Controller (PTC), Event System for peripheral co-operation; custom programmable logic blocks; self-programming for firmware upgrades; non-volatile data storage; 20MHz internal oscillator; high-speed serial communication with USART; operating voltages ranging from 1.8V to 5.5V; 10-bit ADC with internal voltage references; and sleep currents at less than 100nA in power down mode with SRAM retention.

CIPs allow the peripherals to operate independently of the core, including serial communication and analog peripherals. Together with the Event System, that allows peripherals to communicate without using the CPU, applications can be optimised at a system level. This lowers power consumption and increases throughput and system reliability.

Contact:
Microchip Technology Australia
41 Rawson St,Epping, NSW, 2121
Tel: (02) 9868 6733
Web:www.microchip.com

DRONE VOLT'S DV WING: for agriculture and mapping

DRONE VOLT, the French professional drone manufacturer is launching the "DV WING", a flying wing drone dedicated to precision agriculture and construction work.

DV WING is equipped with an 18.2MP sensor and uses algorithms enabling it to obtain aerial imagery and accurate data for missions such as photogrammetry, map analysis for farming areas and forests and measurements for road construction.

The data it collects can be used by farmers to establish accurate diagnostics for the treatment of crops and the management of pesticide use. The DV WING can also be used by quarry and mining operators to measure volumes.

Compact and very light at just 940 grams, the DV WING is easy to use and can be launched by hand.

It has enough battery capacity for autonomous flight times of 85 minutes and the onboard sensor is capable of capturing very high resolution images. It is capable of generating highly accurate ortho-photos.

Contact:
Drone Volt
14, rue de la Perdrix, 95934 Roissy Charles de Gaulle Cedex, France
Tel: (0011) 80 89 4444
Website: www.dronevolt.com

Using Cheap Asian Electronic Modules Part 3

Computer Interface Modules

Want to connect a microcontroller to your PC? How about interfacing with a microSD memory card? These low-cost modules make life really easy! Jim Rowe shows you how.

THE FIRST MODULE we're looking at this month has been used in a number of SILICON CHIP's recent projects. It's a serial USB-UART (universal asynchronous receiver/transmitter) bridge which allows just about any microcomputer or peripheral module to exchange data with a PC, via a standard USB port.

Let's start by explaining what is meant by the rather clumsy term "serial USB-UART bridge". Firstly, a UART is an interface which can operate in one of several different common serial protocols. The serial protocol we're most interested in (and which is most widely used) is 3.3V "TTL" RS-232. The term "bridge" simply refers to the fact that this module allows data to pass between the USB interface and UART interface unchanged.

In fact, we've already described a device with essentially the same purpose, the Microchip MCP2200 "protocol converter" used in the USB/RS-232C serial interface which was published in the April 2014 issue.

Another very similar device is the FT232 chip from the British firm FTDI, which was used in the Elexol USBMOD3 USB interface module in the USB Electrocardiograph project (SILICON CHIP, February 2005).

Note that for a UART to provide a fully compatible RS-232 serial port, as used in many now obsolete PCs, it's necessary to provide level shifting from the UART's 3.3V (TTL) signalling levels to the RS-232 bipolar logic levels of ±3-15V.

But these days, RS-232 is commonly used for short-range communications between microcontrollers and bridges and in this case, the TTL signal levels are all you really need.

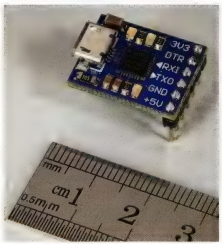
The first serial USB-UART bridge modules to become popular were based around FTDI's improved FT232R converter chips. However, these chips became so popular that some Asian firms made "clones" of them, even going so far as copying the package markings.

Understandably, this upset FTDI and as a result they released a new version of their Windows VCP driver which was able to identify when a clone chip was being used and disable it. This "clone killer" driver was included in an automatic update that Microsoft unwittingly provided to Windows users.

As a result, thousands of people found that their low-cost USB-UART converter modules, some inside commercial products, suddenly stopped working and became worthless. Naturally, this made many people cautious of buying any converter based on the FTDI FT232R chip, because of the difficulty in ensuring that you are buying a genuine FTDI chip rather than a clone chip that would stop working as soon as you tried to use it with Windows.

As a result of this, CP2102-based USB-UART bridges have become very popular. These are not only less expensive than FT232-based modules but are (currently) free from such driver issues.

A good example of this type of module is the tiny one shown in the photo below. This same module has been used in quite a few of our recent projects, such as the Micromite LCD Back-Pack (SILICON CHIP, February 2016) and Touchscreen Appliance Energy Meter



A CP2102 module, measuring only 20 x 16mm. Two of the indicator LEDs glow when data is being transmitted.

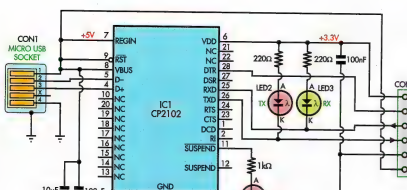


Fig.1: complete circuit diagram for the CP2102-based serial USB-UART bridge. The CP2102 can be powered directly from the USB V_{BUS} line and it contains a low drop-out voltage regulator to provide 3.3-3.45V (V_{DD}) from 4-5.25V (REGIN).

(SILICON CHIP, August-October 2016). In fact, it can be used with virtually any Maximite or Micromite, to program the micro as well as debug the software or load data into or out of the micro's RAM.

The CP2102-based bridge

As you can see from the photo and circuit diagram Fig.1, there's very little in this module apart from the CP2102 chip itself (IC1), three indicator LEDs and half a dozen passive components.

The internals of IC1's tiny (5 x 5mm) 28-pin QFN SMD package are shown in the internal block diagram, Fig.2. It's conceptually quite simple but involves tens of thousands of logic gates and memory cells as well as carefully-designed analog circuitry.

The main functional blocks are the USB transceiver at lower left, the USB function controller at lower centre and the UART block at lower right with its full range of data and handshaking inputs and outputs. Notice that there's also an internal 1024-byte EEPROM used to store the USB ID information: the vendor ID, the product ID, the serial number, the power descriptor, the release number and product description strings.

In addition, there are two RAM buffers, one 640 byte USB transmit buffer and one 576 byte USB receive buffer.

Since the CP2102 has a calibrated 48MHz oscillator, it needs no external crystal to operate at the USB 2.0 full-speed rate of 12Mbps. Finally, it contains its own low drop-out (LDO) voltage regulator, to give an output of 3.3-3.45V from an input (REGIN) within the range 4.0-5.25V. This means that it can be powered directly from the USB V_{BUS} line.

Circuit details

While this regulator can supply up to 100mA, the circuitry within the chip itself draws only a little over 26mA (maximum) even in normal operation and only 100µA when suspended. This means it can supply up to 70mA or so for external circuitry needing a 3.3V supply.

In short, the CP2102 is a very impressive chip. Now turn your attention back to the module's circuit of Fig.1. There's a micro-USB socket at the left (CON1) to connect to a PC's USB port via a standard cable and also to power the module itself. So the V_{BUS} line from pin 1 of the socket connects to pins 7, 8 and 9 of the CP2102, with 10µF and 100nF bypass capacitors.

Note that the module does not provide connections to any of the CP2102 UART's handshaking lines, except for DTR ("data terminal ready"). However this is unlikely to pose a problem for most applications nowadays, since even the DTR line is rarely used.

On the right-hand side there's a 6-way pin header (CON2) for the UART input, output and handshaking (DTR) connections, plus the ground, +5V and +3.3V power connections for use by external circuitry. There's also a 100nF bypass capacitor on the +3.3V line, plus three small indicator LEDs, each with its own series resistor for current limiting.

LED1 is driven from pin 11 of the CP2102, the SUSPEND-bar output, so it only glows when the device is not suspended by the host PC, ie, when it's communicating with the PC normally via USB. On the other hand, LED2 and LED3 are connected between the +3.3V supply (pin 6) and pins 26 (TXD) and 25 (RXD) respectively, to indicate when data is being sent and received via the bridge.

LED1 draws a little over 1mA when it's operating while LED2 and LED3 will each draw about 5mA. Thus the LEDs could draw up to 11mA from the 3.3V supply (with full duplex serial communications, allowing LED2 and LED3 to light simultaneously) and this should be taken into account when figuring out how much reserve current is available for external circuitry.

How to use it

Using the CP2102 based USB-UART bridge module is very straightforward. But before you can do so, you may need to install a virtual COM port (VCP) driver on your PC. This is the software which takes care of buffering data to and from the bridge and setting up the UART. In Windows, it makes the UART appear as if it were a legacy COM port.

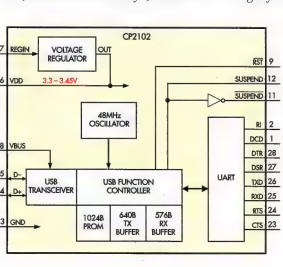


Fig.2: block diagram for the CP2102. This UART interface implements all RS-232 signals, including those for control and handshaking, although an external level shifter is required for full RS-232 compatibility.

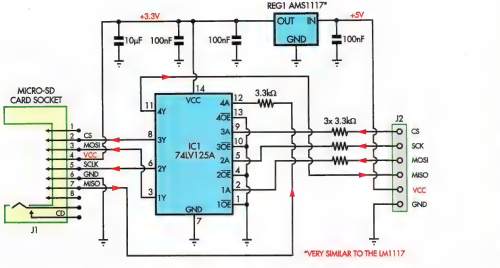


Fig.3: full circuit of the SPI/microSD adaptor module. REG1 reduces the 5V (V_{CC}) input supply from the host module to 3.3V, as required by microSD cards while IC1 similarly reduces signal levels from the micro (which may run off 5V) to the 3.3V signal levels used by the SD card's I/Os.

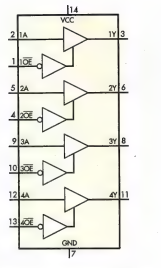


Fig.4: internal block diagram of the SN74LV125A IC. When an $\overline{OE}$ input is pulled high, the corresponding output is disabled and has a high impedance.

You can get the right VCP driver from the Silicon Labs website: www.silabs.com/products/interface/Pages/interface-software.aspx

You can also download the latest version of the CP2102 data sheet from: www.silabs.com/support/Pages/document-library.aspx

When you go there you'll find they can provide VCP drivers for not only Windows 7-10, but also for Windows 2000/XP/Vista/Server 2003, WinCE, Mac OS 9 and X, Linux (3.x.x and 2.6.x) and Android. They can also provide drivers for direct "USB-Xpress" interfacing to the PC, as an alternative to using the VCP approach.

Note that most modern operating systems, including Windows 10 and the latest versions of Mac OS X and Linux, should already have a suitable VCP driver installed. In this case, all you need to do is plug the bridge into a USB port and check that it has been recognised (eg, in Windows, check that a new COM port appears).

Once the driver is installed and working, you can set up your applications to communicate with the module via the new COM port. That includes setting the correct baud rate and other options.

Of course, your circuitry on the UART side of the module needs to be connected to the appropriate pins on header CON2. These will usually be just the RXI, TXO and GND pins, although you might also want to make use of one of the power supply pins as well.

If you aren't sure whether the bridge is working properly, the simplest way to test it is to wire up the RXI pin to the TXO pin. You can then open a terminal emulator, connect to that port and type on your keyboard. The typed characters should be sent back to you and appear in the terminal. If that works, but you still can't communicate with your target device, check that the connections to its TX/RX pins are not swapped and also that you have set the right baud rate.

microSD card interface

There are many different adaptors for accessing an SD memory card from a microcontroller or embedded module but they generally function in the same manner. The main differences are in terms of the card socket they provide and the chip(s) they use for interfacing.

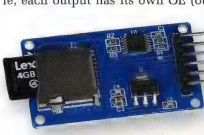
The full circuit for this module is shown in Fig.3. Note that all SD cards can communicate via either serial peripheral interface (SPI) or a faster method, which consists of either a 4-bit parallel bus (older cards) or a high-speed differential interface (UHS-compatible cards). The SPI method is by far the simplest to implement with a microcontroller, unless it has a built-in SD card interface.

The other important thing to note is that all SD memory cards are intended to run from a 3.3V power supply and expect logic signals no higher than +3.3V. Some cards can only accept signals swinging over a smaller range, like 0-1.8V (UHS-I) or 0-0.4V (UHS-II).

Just because a chip has an SPI interface doesn't mean it can necessarily interface directly with an SD card. If the micro operates from a 5V supply, its SPI port(s) may well provide and expect logic high signals above +3.3V. This means that the adaptor is needed both to drop the supply voltage down to 3.3V (assuming a suitable rail is not already available elsewhere) and also to act as a logic level translator for the SPI signals.

The module shown here incorporates LDO regulator REG1 to drop the +5V supply voltage from the micro (via J2) down to the +3.3V needed by both the microSD card at J1, and the single chip (IC1) on the module itself.

IC1 is an SN74LV125A tri-state buffer, to interface between the 5V logic levels (TTL) used on the micro side (via J2) and the low-voltage (0-3.3V) logic levels used on the SD card side (via J1). IC1 operates as a quad non-inverting buffer with tri-state outputs, ie, each output has its own $\overline{OE}$ (out-



This microSD module on a 43 x 24mm PCB is available from the Silicon Chip online shop at: www.siliconchip.com.au/Shop/7/4019

put enable low) input; see the internal block diagram of Fig.4. The $\overline{OE}$ inputs are not used, they are all tied to ground to enable the buffers permanently.

If you trace the signal paths through the circuit, you'll see that the three outgoing signal lines from the micro's SPI port at J2 (CS [card select], SCK [serial clock] and MOSI [data; master out, slave in]) each pass through a 3.3kΩ isolating resistor (to reduce ringing and provide some static electricity protection) and then through one of the buffers in IC1 to reach the corresponding pin on SD card socket J1.

For example, the 5V MOSI signal enters via J2, passes through its 3.3kΩ resistor and then goes to buffer input 1A (pin 2). The low-voltage logic version of this signal then emerges from the 1Y output (pin 3) and runs to the MOSI pin of J1, the microSD card socket.

The SCK and CS signals are processed via IC1 buffers 2 and 3 in the same way. The path followed by the MISO (data; master in, slave out) signal is similar, the only difference being that in this case the signal is travelling from the microSD card at J1 back to the micro at J2. Note though that the circuit does not level-shift this signal to 5V, so the micro will have to cope with a data input signal that only swings up to around 3.3V; most 5V micros are capable of this.

So the hardware side of the module is quite simple. Having said that, the SD card control protocol is quite complicated and so the software required to drive it is far from trivial.

Putting it to use

Since the module simply provides a transparent bridge linking the microSD card to the SPI port of your microcomputer, the software or firmware in the micro can exchange data with the card using the standard SPI commands. So with an Arduino, you can use commands like:

```
SPI.beginTransaction(SPISettings());
receivedVal = SPI.transfer(val);
SPI.end();
```

There's also an Arduino code library built into recent versions of the Arduino IDE, designed especially for reading from and writing to SD cards. It offers commands like begin(), mkdir(), open(), remove(), rmdir(), available(), close(), write() and read().

With a Micromite it's also fairly straightforward, using commands like:

```
SPI OPEN speed, mode, bits
received_data = SPI(data_to_send)
SPI CLOSE
```

However, the Micromite Plus has built-in library commands specifically intended for reading and writing to SD cards; see the article on Micromite programming on page 58.

Useful links

Information on using standard SPI commands with an Arduino, including some short examples, can be found at: **www.arduino.cc/en/Reference/SD**

Details on using SPI communications with a Micromite begin on page 92 of the Micromite manual: **http://geoffg.net/Downloads/Micromite/Micromite%20Manual.pdf**

An article on the SPI bus is available at: **http://en.wikipedia.org/wiki/Serial_Peripheral_Interface_Bus**

Wikipedia also has a very informative article on the many kinds of SD cards, at: **http://en.wikipedia.org/wiki/Secure_Digital** SC

Glossary

COM Port: PC communications port, normally sending and receiving data using the RS-232 serial protocol.
CS (Card/Chip Select): used in an SPI bus to indicate when the master wants to communicate with a slave (pulled low).
DTR (Data Terminal Ready): a "flow control" signal which is used to indicate when the serial port is ready to receive data. Other, related flow-control signals include DSR (Data Set Ready), CTS (Clear To Send) and RTS (Ready To Send).
EEPROM (Electrically Eraseable, Programmable Read-Only Memory): non-volatile memory that can be erased and rewritten by applying a higher voltage than is used to read data back. EEPROM is normally more robust than flash.
LDO (low drop-out [regulator]): a regulator which can maintain regulation with less than 2V between its input and output.
Micromite: a Microchip PIC32 programmed with the MMBasic interpreter.
MISO (master in, slave out): the serial data line used to transmit data from the selected slave to the master in an SPI bus.
MOSI (master out, slave in): the serial data line used to transmit data from the master to the selected slave in an SPI bus.
QFN (Quad Flat No-lead): a standard series of surface-mount integrated circuit packages. As the name suggests, it is attached to a PCB without through-holes via lands (pads) on the bottom and sides of the package (ie, without leads).
RS-232 or EIA-232: one of the most common standards for serial communications. Used by the serial ports on older PCs. Uses one wire for self-clocked data in each direction plus optionally, several flow control signals.
RX or RXD: serial data receive line. Normally connected to TX or TXD on the other device.
Serial Communication: the process of transferring data one bit at a time over a communication channel or bus.
SCK (Serial Clock): the shared clock line in an SPI bus, driven by the master, typically up to 20MHz.
SD (Secure Digital): a non-volatile portable storage device utilising flash memory. Successor to MMC (MultiMedia Card).
SPI (Serial Peripherial Interface): a standard serial interface bus, commonly used between a microcontroller and peripherals such as SD cards. Unlike RS-232, SPI has a separate clock line, ie, three wires for bidirectional communications.
TTL (Transistor-Transistor Logic): refers to digital signals with a 5V or (later) 3.3V amplitude, as used in early digital circuits.
TX or TXD: data transmission line. Normally connected to RX or RXD on the other device.
UART (Universal Asynchronous Receiver/Transmitter): circuitry which handles sending and receiving of serial data using one of several different serial protocols or variations thereof.
USB (Universal Serial Bus): high speed serial bus with power (initially using four conductors) which replaced RS-232 and parallel ports for interfacing a PC to pluggable peripherals; from 1.5Mbps up to 5Gbps in the latest version.
UHS (Ultra High Speed): transfer speed for the latest SD cards; up to 104MB/s for UHS-I, and 312MB/s for UHS-II.
VCP (Virtual COM Port): a device driver that emulates an RS-232 serial port over a different protocol such as USB.

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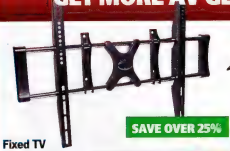

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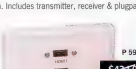

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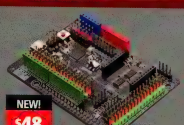

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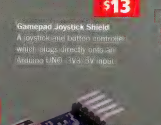

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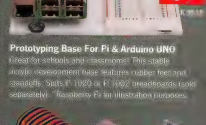

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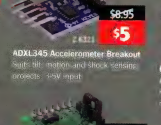

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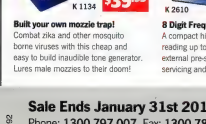

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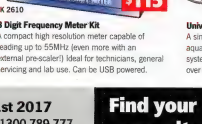

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Improving your Arduino-based Theremin

By BAO SMITH

Last month we had a short article on building an Arduino-based digital Theremin which may have left some a bit wanting. This month we show how to add a second sensor onto the Theremin which is used to control volume.

You can't really call something a Theremin if all it does is alter pitch. So, we decided to improve on the Theremin kit from Jaycar by adding a second ultrasonic sensor which is used to alter volume.

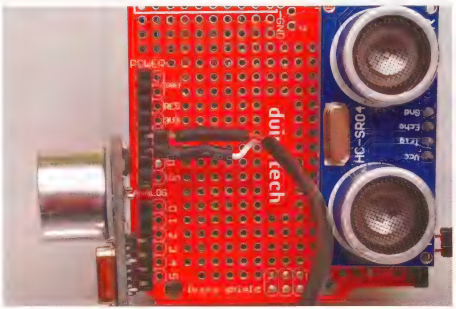
This extra HC-SR04 ultrasonic sensor is cheap – it can be bought from Jaycar for $7.50 (Cat. XC4442).

Adding the second sensor

The second sensor is aimed perpendicular relative to the first and moving your hand closer to it increases the volume, decreasing it if you move away.

While the physical change to this kit is very simple, there is much more that needs to be altered on the software side to provide the volume-altering effect.

Because of the lack of space around the DIGITAL pins due to the pitch-controlling sensor being located there, we opted to plug the second sensor into the ANALOG pins.



The second ultrasonic sensor is fitted so that V_{CC} goes to ANALOG pin 2, while Trig goes to pin 3. Note that the amplifier power lead has been bent slightly so that there is better spacing between parts.

Conveniently, the ANALOG pins on the Arduino Uno can be used as digital pins, however, when manipulating them, the pin number needs to be prefixed with 'A', ergo A2 corresponds to ANALOG pin 2 on the board.

We have placed the addition sensor with V_{CC} on ANALOG pin 2. Trig on pin 3, Echo on pin 4 and GND on pin 5. We also slightly bent the 2-pin male header that the amplifier power supply connection was attached to so the lead does not come into contact with the sensor.

As detailed in last month's article, the pin locations of the new sensor can be altered (if necessary) by changing what is defined in the software. But it's easiest to use the same pins we have.

Then all that needs to be done is upload the new software to the board. The new software will still work with just one sensor, as shown last month, and can be downloaded for free from our website www.siliconchip.com.au

Software

Once again, the software details are left to an interested reader. Instead, we will just go over some of the more important points. At the top of the **Ultrasonic_Theremin.ino** file there is a new macro called VOL_SENSOR which is set to 1 by default.

When set to 1, the software will act as if both sensors are attached, and thus attempts to request data from both sensors. If set to 0 the software functions as if only the pitch-controlling sensor is attached and thus only polls one sensor.

The amplifier's audio signal level is determined by the value of the 8-bit OCR2B register, which can range between 0 to 255 inclusive.

Now that we have the additional sensor, a second distance measurement is computed (simultaneously with the first, to avoid slowing down the feedback loop). This distance measurement is then used to scale the sinewave value written to the OCR2B register, effectively attenuating the sound level depending on how far your hand is from the new sensor.

By default, the software uses the same MAX_DIST setting for both sensors to set their maximum detection range. If for some reason you wanted to use a different value for each sensor, you would need to modify the software.

The trickiest part of modifying the software to handle two sensors was the code to measure the distance for each simultaneously. This involves sending simultaneous trigger pulses, then waiting for both echo pulses to be received while separately timing the start and end of each echo, so that we can later subtract them and calculate the distance measured. We recommend that interested readers take a close look at this part of the source code to see how we did it.

Of course, one of the great things about Arduino is that you can download our software and easily experiment with making changes to see what effect they have.

More Arduino projects

If you're interested in building other Arduino projects, check out Jaycar's guides at: www.jaycar.com.au/arduino SC

While many readers will be familiar with electronic circuit simulation by programs like Spice or system design software such as LabVIEW, there are also simulation programs to test mechanical systems like motors. Simulink is a graphical programming language developed by MathWorks and it can be used to test Arduino control systems.

By Karthik Srinivasan*

Real-time system modelling with Arduino and Simulink

This practical demonstration involves using Simulink to analyse the operation of a standard radio control servo (Hitec HS-422) under Arduino control. Simulink can simulate faults and it allows the user to make alterations to the system to correct any faults in real time.

Note, that the rest of this article assumes some familiarity with control theory, linear regression and related concepts.

When designing any system, criteria such as gain and phase margins can ensure acceptable performance when there are slight changes in system dynamics. However, if system dynamics were to change significantly because of a component or sensor failure, the result can be less than optimal or even catastrophic.

To ensure that these types of failures do not produce an unexpected result, it is important to detect these events as they happen. A real-time model lets you compare actual system measurements with predictions from the model and detect failures when the difference exceeds a certain threshold.

This article details how to build the base of the model, and also how to acquire data from an Arduino device. You can find it at **www.siliconchip.com.au/l/aaak** and it includes a download of the source code.

A video version of this article can be found here: **www.siliconchip.com.au/l/aaal** and another related video here: **www.siliconchip.com.au/l/aaam**

For this demonstration we use a Hitec HS-422 servo (widely used in radio-controlled model cars, boats and planes) mounted on a motor driver which is connected to an Arduino Duemilanove board (an Arduino Uno board can be substituted).

In Fig.1, we have the servo track a square wave reference angle and after 20 seconds we introduce a disturbance

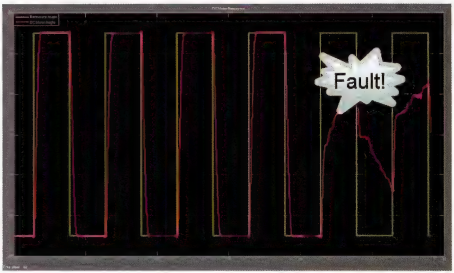


Fig.1: the predicted (yellow) and measured (mauve) motor angle. The measured motor angle does not go back to a rest position once the fault has been introduced into the system.

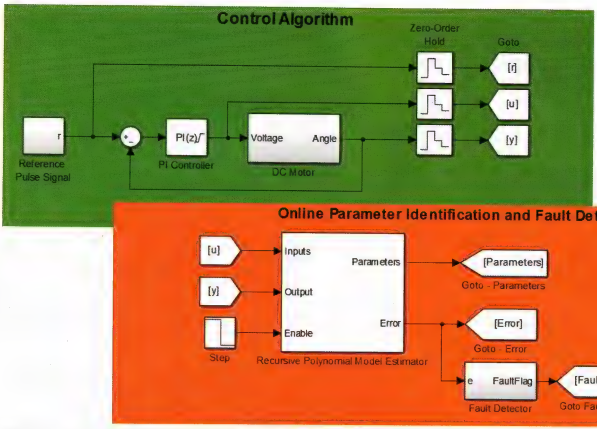


Fig.2: the Zero-Order Holds in the control algorithm provide a specified time-delay for the inputs provided, here we leave it at the default value of 1. The polynomial estimator performs the comparison between the measured and predicted motor angle, it then calculates the absolute error and original parameters. The data then needs to be sent to a host computer so it can be plotted.

to the system, stopping the servo motor from tracking the reference angle.

Since we want to be able to detect this change in behaviour while the servo motor is running, we program the Arduino Duemilanove board to perform this calculation.

Fault detection

To program the Arduino Duemilanove we build a two-part model in Simulink using blocks from the System Identification Toolbox (Fig.2).

The first part of the model is the control algorithm and it uses motor angle measurements and a PID (proportional-integral-derivative) controller to send a voltage request to the servo motor which then tracks the reference angle position.

The PID controller looks at the set-point value provided and compares it to the actual value of the process variable; in this case the reference angle of the motor. It then returns low if both values are the same, or high if they differ too much.

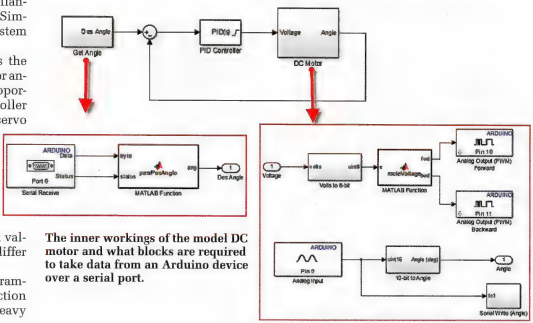
The second model handles parameter identification and fault detection and this is where the maths gets heavy (After all, it is from MathWorks!). It uses a "recursive polynomial estimator" block located in the System Identification Toolbox which has inputs for the input motor voltage and measured angle.

This is configured as an ARMAX (autoregressive-moving-average exogenous) model that is used to estimate an ARMAX polynomial with the form:

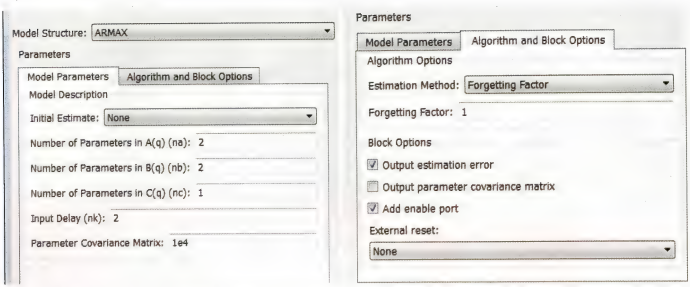
$$\mathbf{A(q) * y(t) = B(q) * u(t - nk) + C(q) * e(t)}$$

This lets us model noise and dynamics independently.

Choosing the right parameters for our ARMAX model is part science, part trial and error. Since any DC motor can be modelled as a second-order differential equation, we choose two



The inner workings of the model DC motor and what blocks are required to take data from an Arduino device over a serial port.



Figures 3 & 4: an ARMAX polynomial is used for comparison between the measured and calculated motor reference angle and the value of each parameter should be set as follows in the menus above. The "Output estimation error" selection is needed so that we can plot the difference between our results.

for the number of poles [A(q)], two for B(q) and one for C(q) as shown in Fig.3.

For the input delay (nk), we record how long the servo takes to respond to a step input and divide this number by the estimator sample time, providing us with a value of two (milliseconds) for our model.

The input delay can be treated as phase shift or a time delay applied to the polynomial.

In Fig.4, the recursive polynomial estimator block gives us the option to enable or disable parameter estimation. We use "Add enable port" to perform 'online' parameter estimation for the first 10 seconds of runtime – this provides time for the parameters to converge to their steady state values.

Once this period has passed, the parameter estimation block stops updating the servo motor with new values; instead it uses the previously estimated values to calculate the next step.

These estimated values are used to predict the motor angle for a given motor input voltage (under normal operating conditions) and are then compared to the measured motor angle. This is how the error for the motor system is calculated.

Simulink provides a way to calculate a steady state error of the system. To do this we enable the error port which outputs the one-step-ahead prediction error (the difference between the measured motor angle and the predicted angle).

We use a low-pass filtered version (ie, another pole) of the fault detection algorithm, which is implemented as a two-state StateFlow chart; which is a finite-state machine (Fig.5).

The StateFlow chart sets the fault flag high when the filtered error is greater than the threshold value which is currently 1 and sets the flag low when 10 seconds have passed and the error is less than 1.

This Simulink model is now loaded onto the Arduino Duemilanove board by using the "Run on Target" feature of Simulink.

Result

Everything is set to detect changes in the servo's dynamics while it is running and in Fig.6 we can see our results. We have the parameter estimation algorithm calculate the approximate servo motor dynamics during the first 10 seconds of runtime before it reaches its steady state.

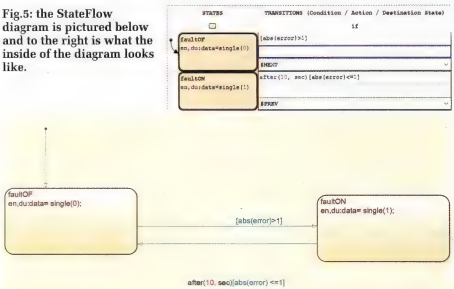
After around 20 seconds have passed we introduce our disturbance into the servo motor, this causes the error value to shoot up and the fault detection algorithm sets its fault flag high.

Once the disturbance is removed, the system returns to normal and the fault flag is once again set low.

Building on this approach

For this project, we use real-time estimation to detect faults as they occur in our system.

Fig.5: the StateFlow diagram is pictured below and to the right is what the inside of the diagram looks like.



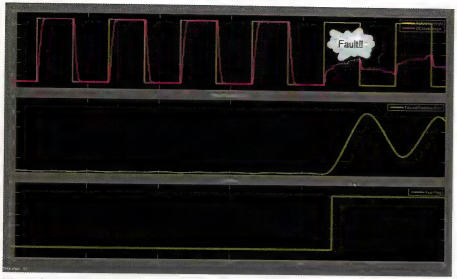


Fig.6: the top yellow trace is the predicted (or control) motor angle while the mauve trace is the measured angle. The plot below shows the fault prediction error (the difference between the predicted and measured values). Below that is the fault flag value; it steps high when the error rises above a set constant.

Common applications of this are in adaptive control, where this technique is used to modify some controller based on changes to the system helping to maintain a required level of performance.

For example, some radio control (RC) servo motors use adaptive control to correct the performance of its mechanism. An odd example would be a swing driven by a motor with an adaptive control system to help sustain periodic movement.

After making sure the prototype model is correct, Simulink provides an easy way to generate code for your model, letting you deploy it to your target hardware, similar to how we loaded the software onto an Arduino Duemilanove board using the "Run on Target" feature.

Contact and pricing

A free 30 day licence for the MathWorks suite which includes Matlab, Simulink, StateFlow and more can be applied for on the MathWorks website (https://au.mathworks.com/) by clicking the Trial Software link at the bottom of the page.

Pricing details for each type of licence can also be found on their website and more example projects can be found at http://makerzone.mathworks.com/

* MathWorks SC

Extra Reading

https://au.mathworks.com/help/instrument/direct-interface-communication-in-simulink.html – using serial communications in Simulink

http://au.mathworks.com/help/supportpkg/arduino/ug/run-model-on-arduino-hardware.html – running Simulink programs on Arduino

https://au.mathworks.com/help/ident/ref/recursivepolynomialmodelestimator.html – recursive polynomial estimator block

http://au.mathworks.com/help/ident/ref/armax.html – ARMAX function

https://en.wikipedia.org/wiki/Autoregressive-moving-average_model – ARMA details

http://au.mathworks.com/help/ident/examples/comparison-of-various-model-identification-methods.html – model comparisons

www.facstaff.bucknell.edu/mastascu/eControlHTML/Design/Perf1SSE.htm – steady state error details

https://au.mathworks.com/help/stateflow/gs/anatomy-of-a-stateflow-chart.html – StateFlow chart example

www.landau-adaptivecontrol.org/Slides%20Ch1.pdf – slides on adaptive control compared to conventional and robust methods

www.google.com.au/patents/US5833545 – adaptive control swing patent

http://au.mathworks.com/matlabcentral/fileexchange/44416-simple-adaptive-control-example – example program using adaptive control

Glossary

Exogenous variable: variables independent of the process being measured; an example could be a shift in consumer confidence leading to lower sales, or a natural disaster affecting energy production.

Online: the model or plant being run during the runtime of the system being tested, ergo in real-time.

Pole: poles and zeros are terms applied to mathematical transfer functions. In electronic circuitry, every filter network has a time constant, a rolloff frequency and associated slope and a phase characteristic. Each filter network, which may be as simple as an RC low-pass network, is referred to as a "pole". The filter network which is the main determinant of a circuit's frequency response is referred to as the "dominant" pole.

Plant: a term from control theory referring to the combination of an input and output signal with some component that is responsible for controlling a mechanism or system.

Polynomial: a polynomial is an expression that can be expressed in the form: $a_n x^n + a_{n-1}x^{n-1} + \ldots + a_1 x + a_0$ where $a_0, \ldots, a_n$ are constants, x_n are unknown variables and $n \geq 0$.

Servo motor: a servo motor contains a DC motor, gear reduction unit, a position-sensing device (normally a potentiometer) and a control circuit. A servo receives some control signal that represents the desired output motor angle of the shaft and applies power to the motor until that angle is reached; the position-sensing device is used to determine which way the motor should move.

Transfer Function: a mathematical function relating the output or response of a system to its input, eg, a filter circuit.

LOW COST HDTV SET-TOP BOXES

...with recording to USB memory

Did you know that high-definition digital set-top boxes make great personal video recorders when used with a USB flash drive or external (USB) hard disk? And the best part is they're really cheap! Jim Rowe compares five commonly available units.

Modern set-top boxes offer a lot more than earlier models, despite their sub-$80 prices. This makes them well worth considering for uses like recording late-night programs for watching at a more convenient time. In most cases they're also capable of being used as a 'media hub', for playing videos downloaded from the web on your TV.

An important feature is the ability to record programs onto a USB flash drive, an external USB SSD drive or a USB portable hard drive. This means they're no longer just an STB but a personal video recorder or "PVR", as well. So since USB flash drives or "thumb drives" are available with capacities up to 64GB and beyond at very attractive prices, this means you can junk your old DVD+/-R recorder (or even older VCR) and record late-night TV programs very easily for viewing at a more convenient time. There's no need to invest in one of those $250-plus PVRs with an internal 500GB or 1TB hard drive, either.

Putting things into perspective, a 4GB USB flash drive can hold about an hour of HDTV or around two hours of SDTV. You can double these times for an 8GB drive, double them again for a 16GB drive and so on. This means that a 32GB thumb drive will hold about eight hours of HDTV programs, or 16 hours of SDTV – not bad for a drive you can currently buy for around $15 or even less! In most cases, you do need to use USB 2.0 or 3.0 drives with these STBs, especially for HDTV recording and playback. USB 1.1 drives probably won't be fast enough for STB use.

So how easy is it to make a recording – can you simply press a button on the remote control to start or finish it? Most STBs do allow this but generally they also provide the ability to set the start and finish times in advance, using the built-in electronic program guide (EPG).

Many also allow you to use the USB recording function for time-shifting or 'live pause' viewing. This allows you to set it to record the program being viewed if you are called away for some reason, and then start watching it again when you return (from the point where you left), simply by pressing the Play button. Since it continues to record the program while you are playing it back, none of the program is lost – assuming there is enough space for it on the USB drive.

You may be wondering if they are all capable of recording the range of SD and HD signals currently being broadcast in Australia. The answer to this is generally yes, since at present all of the DVB-T transmissions are being encoded in three main formats, as shown in the table opposite. And all of the STBs currently available seem to have no trouble handling these formats, as you'll read shortly.

Some quick comments about aspect ratio and picture resolution. First, remember that nominally all Australian DVB-T stations transmit a picture with an aspect ratio (width/height) of 16:9, or 1.78:1. But if you divide the 'active pixels' on each line by the number of lines shown in the small table, you'll find that the only format that seems to give this ratio is the 'HD'/720p format (1280/720 = 1.78:1). The SD/576i format gives 720/576 = 1.25:1 or 5/4, while the FHD/1080i format gives 1440/1080 = 1.33:1 or 4/3.

The only apparent exception is 9HD in Perth WA, which

The five commonly-available set-top boxes we reviewed, with the rear panel shown above and the front opposite. On top is the Dynalink A2809, with the Laser STB-6000 under that, followed by the Strong SRT5432, the Teac HDB850 and finally the Digitech XC4929.

does provide 1920 active pixels per line and thus can transmit video with an aspect ratio of 1920/1080 = 1.78:1 or 16/9.

So what's the secret? How is it possible for those SD/576i stations and most of the FHD/1080i stations to transmit a 16/9 picture? Well, in the above calculations we were assuming that the pixels making up each line were square in shape. But the stations can achieve a 16/9 aspect ratio quite simply by using elongated pixels to make up each line. The only format that actually uses square pixels is the HD/720p format used by ABC News24.

The other thing to bear in mind is that although each of the three DVB-T formats shown in the table below has a rated picture resolution, this is essentially the maximum resolution it can provide. The actual resolution (and aspect ratio) depends very much on the program material being transmitted – which can vary significantly.

Multimedia hubs

Another handy feature offered by most of these latest STBs is that they can also be used as a 'multimedia hub' - to play back through your TV many of the common types of multimedia that can be recorded on a USB drive. This includes digital photo images and music as well as movie clips, in most of the file formats that can be downloaded from the internet.

These digital image formats can usually be displayed: JPEG, BMP and PNG; and the audio formats: MP3, PCM, WAV, OGG and MP4; and finally the video formats: AVI, VOB, MOV, MKV, WMA, MPEG2 MP@HL and MP4/H.264 MP&HP@L4.1.

Many of the STBs will also 'play' full HD 1080p MP4/H.264 HP@L4.1 files - known as the 'Blu-Ray disc' format. But at present none of them will play files in the newer and higher resolution "2K" or "4K" formats.

Let's now move on to look at five representative models of the currently-available low-cost HD STBs. We will be looking at them one by one, but before we do so please refer to the large comparison table where we have summarised many of their important technical details. We'd also like to make a few general comments which apply to all of them.

How we checked them

We hooked up each one to a 42" high definition (1080p) LCD TV, looping its RF input and output into the TV's antenna cable and connecting the STB's HDMI output to one of the TV's HDMI ports. We checked its basic performance as a DVB-T set-top receiver 'front end'. All of them performed this key role with no problems – receiving all the local DVB-T broadcasts with excellent video and sound quality.

We then tried making test recordings from three local DVB-T stations – one using the SD (576i) format, one (ABC News 24) using the HD/720p format, and one using the FHD (1080i) format. In each case they're all excellent performers.

To check out their capabilities as multimedia playback hubs as well, we downloaded a number of 1080p and 720p video files (movie trailer clips, actually) from www.h264info.com/clips.html, plus a few 480p video files as well (from https://archive.org/) and some MP4/H.264 test pattern files (from www.w6rz.net). All of these files were copied to another 8GB USB 2.0 flash drive.

Here again, most of them played pretty well all of these files with excellent results. There were a few problems which we'll discuss shortly. But overall, the results were very impressive.

Right – now let's look at each of the five STBs in turn.

CURRENT AUSTRALIAN DVB-T FORMATS

TYPE	FORMAT	RESOLUTION	COMMENTS
SD	576i	576 lines x 720 active pixels	All SD broadcasts are currently in this format
HD	720p	720 lines x 1280 active pixels	Currently only ABC News24 uses this format
FHD	1080i	1080 lines x 1440 active pixels	NineHD in Perth has 1920 active pixels/line

NOTES: (1) 'i' indicates interlaced scan, 'p' indicates progressive scan
(2) DVDs use 720p (720 x 576 x 50Hz for PAL, 720 x 480 x 60Hz for NTSC)
(3) Blu-Ray discs use 1080p (1080 lines x 1920 active pixels)

While this list is current at press time (December 2016) it is quite likely to change in the reasonably near future, as TV stations re-organise and rationalise their channeling.

Dynalink A2809

The Dynalink STB is available from Altronics (www.altronics.com.au) and its resellers. Despite carrying the highest price of the five ($79.95), it's the smallest of them,

About H.264/MPEG-4 AVC

H.264 is also known as MPEG-4 Part 10 Advanced Video Coding, MPEG-4 AVC or even MP4/H.264 for short. Essentially it's an improved digital video compression standard, designed to provide good video and audio quality at substantially lower bit rates than previous standards like MPEG-2 or MPEG-4 Part 2. For example it offers a bit rate of less than half that of MPEG-2, which is why it has become the preferred standard for encoding Blu-Ray discs - and also for downloading video files over the internet.

The H.264 standard is best viewed as a 'family' of standards, since it can be used to encode many different file profiles, from low-resolution files for viewing on handheld devices right up to 1080p HD video and the newer 4K and 8K even higher resolution formats.

HDTV SET-TOP BOXES WITH USB PVR ABILITY – A DETAILED COMPARISON

BRAND, MODEL & SOURCE	COST	VIDEO FORMATS	VIDEO DECODING FORMATS	AUDIO DECODING	AV OUTPUTS	USB PORT(S), LOCATION	USB CAPACITY SUPPORTED	USB FORMATS SUPPORTED
DYNALINK A2809 (ALTRONICS)	$79.95	16:9, 4:3, P/S, LB 1080p/1080i/ 720p/576p/576i/ 480p/480i	MPEG4 AVC/H.264 HP@L4, MPEG-2 MP@ML,HL	MPEG-1 Layer 1&2	HDMI, CVBS (3.5mm SOCKET)	1 x USB 2.0, RH SIDE PANEL	NOT SPECIFIED, BUT >32GB	NTFS, FAT32, FAT16
DIGITECH XC4929 (JAYCAR)	$69.95	16:9, 4:3, P/S, LB 1080p/1080i/ 720p/576p/576i/ 480p/480i	MPEG4 AVC/H.264 HP@L4, MPEG-2 MP@ML,HL	MPEG-2 Layer 1&2, MPEG4 AAC, MP3, AC-3, LPCM, DTS, WAV, OGG, FLAC, ABR, CBR, M4A	HDMI, YPbPr, CVBS (6 x RCA), SP/DIF AUDIO OUTPUT (RCA)	1 x USB 2.0, FRONT PANEL	<=2TB	NTFS, FAT32, FAT16
STRONG SRT5432 (BIG W)	$69.00	16:9, 4:3, P/S, LB 1080p/1080i/ 720p/576p/576i/ 480p/480i	MPEG-2 MP@ML, H.264 MP&HP@L4.1, (MPEG4), DV, DivX	MPEG-2 Layer 1&2, MPEG4 AAC, MP3, AC-3, LPCM	HDMI (V1.3C), CVBS (3 x RCA), SP/DIF AUDIO OUTPUT (RCA)	1 x USB 2.0, FRONT PANEL	<=1TB	NTFS, FAT32, FAT16
TEAC HDB850 (JB HIFI)	$59.00	16:9, 4:3, P/S, LB PAL-25 @ 720x576, NTSC-30 @ 720x480, 1080p/1080i/ 720p/576p/480p/ 576i/480i	MPEG-2 MP@HL, H.264 MP&HP@L4.1, VC-1 MP@HP & AP@L3	MPEG-1, MPEG-2, MP3, WMA, AAC-LC	HDMI, YPbPr, CVBS (6 x RCA), SP/DIF AUDIO OUTPUT (RCA)	1 x USB 2.0, FRONT PANEL	<=2TB	FAT32, FAT16
LASER STB-6000 (BIG W)	$28.00	16:9 & 4:3, 1080i (NTSC/PAL) 720p (NTSC/PAL) 576i/576p (PAL) 480i/480p (NTSC)	MPEG-2 MP@ML,HL, MPEG4 AVC/H.264 HP@L4	MPEG-1 Layer 1/2/3, WMA, AC-3	HDMI (V1.3C), CVBS (3 x RCA)	1 x USB 2.0, FRONT PANEL	<=750GB	NTFS, FAT32

measuring only 118 x 100 x 28mm and weighing only 113g.

It can operate from 12V DC – making it suitable for use in vans and RVs and even "off the grid" rural properties. As well, it comes with a 230VAC/12V DC plugpack supply to allow use in urban locations. It also comes with an IR sensor extension lead, to allow the unit's remote control to be used from a greater distance.

On the other hand, it doesn't provide component video outputs, making it less suitable for use with older TVs lacking an HDMI port.

Similarly, although three of the other STBs provide an S/PDIF coaxial digital audio output, this is again missing on the A2809.

Four buttons near the left-hand end of the front panel duplicate the functions of four of the buttons on the remote (Power on/off, VOL+/CH+, VOL-/CH- and Menu/Exit). So if you misplace the remote, you will be able to turn the A2809 on, change channels and adjust the volume.

There were no problems when we tried out its functions as a DVB-T receiver front end or a USB-based PVR. Surprisingly it did seem to have problems playing a couple of the H.264/MP4 multimedia files. For example it wouldn't play the video of the 1080p 'The Simpsons' movie trailer (1920 x 800p), only the audio, displaying a 'VIDEO NOT AVAILABLE' message – even though all of the other STBs played both the video and audio without any problems.

Similarly, it alone refused to play a 'Philips Circle' 16x9 test pattern file (H.264/MP4 1280x720p @ 29.97Hz), proclaiming it an 'UNSUPPORTED FILE'.

It certainly performs the basic roles of a DVB-T STB and a USB-based PVR as well as any of the others – together with the "bonus" ability of operating from 12V DC.

Digitech XC4929

The Digitech XC4929 is available from Jaycar Electronics (www.jaycar.com.au) and its resellers. It is listed at $69.95. Measuring 220 x 170 x 45mm and weighing 530g, it's the largest of the five STBs we're comparing here.

In addition to the features listed in the main comparison table, the XC4929 also provides a set of control pushbuttons on the front panel. Again, these duplicate most of the main control buttons on its remote control: Power on/off, Menu, OK and the four channel select and volume adjust buttons (CH-, CH+, VOL- and VOL+).

There were no problems when we tried out the XC4929's functions as a DVB-T receiver front end, a USB-based PVR or a multimedia hub.

It received all of the local broadcasts quite happily and recorded each of the formats with a video and audio quality indistinguishable from the original. And it played all of the H.264/MP4 1080p, 720p and 480p files copied to our test USB drive very nicely indeed.

The XC4929 operates only from the 230V AC mains.

Strong SRT5432

The Strong SRT5432 is currently available from Big W stores for $69.00. It's quite modest in size, measuring 160 x 104 x 28mm and weighing only 173g. That doesn't include its 5V/2A plug-pack.

Inspection showed up only one feature in addition to those listed in the comparison table: three small buttons at the right-hand end of the front panel, duplicating the Power on/off, Up and Down arrow buttons on the remote.

As shown in the comparison table, while the SRT5432 does provide a coaxial S/PDIF digital sound output on the rear panel, it doesn't provide component video outputs – only the HDMI output and composite AV outputs.

When we first powered up the SRT5432, the remote control seemed to be "dead". After doing the usual battery checks we finally worked out what was wrong.

Inside the remote control's battery compartment, the vertical slots in the ends of the compartment intended to accept the positive 'pips' of the two AAA cells were just too narrow, so the pips could not protrude in far enough to make good contact with the metal electrodes inside. It was either a design fault or a plastic moulding fault.

We carefully widened the slots in the plastic with a rotary milling tool. When the cells were refitted, the remote control sprang to life.

After this there were no further problems when we tried

IR REMOTE CONTROL?	ELECTRONIC PROGRAM GUIDE (EPG)?	TIMER TV RECORD?	RECORD & PLAY AT SAME TIME FOR TIMESHIFT?	MULTIMEDIA PLAYER CAPABILITY?	FRONT PANEL DISPLAY	OPERATING/ STANDBY POWER	QUICK START/USER MANUAL?	PHYSICAL SIZE (mm), EXTRAS	COMMENTS
√	√	√	√	√	4 x 7-SEGMENT LEDS	<8W, <1W IN STANDBY	USER MANUAL (140 x 105mm, 25pp m/fold)	118 x 100 x 28, REM. IR SENSOR FOR REMCON, CVBS OUTPUT CABLE	CAN OPERATE FROM 12V DC (COMES WITH 230VAC/12V DC PLUG-PACK)
√	√	√	√	√	4 x 7-SEGMENT LEDS	<8W, <1W IN STANDBY	USER MANUAL (168 x 120mm, 32pp)	220 x 170 x 45, CVBS OUTPUT CABLE	OPERATES FROM 230VAC ONLY. REVISED USER MANUAL CAN BE DOWNLOADED IN PDF FORM FROM www.joycar.com.au
√	√	√	√	√	4 x 7-SEGMENT LEDS	<25W, <1W IN STANDBY	USER MANUAL (140 x 100mm, 20pp)	160 x 104 x 28, CVBS OUTPUT CABLE.	COMES WITH 5V DC PLUG-PACK. QUICK START SHEET & USER MANUAL CAN BE DOWNLOADED IN PDF FORM FROM www.strong.com.au
√	√	√	√	√	4 x 7-SEGMENT LEDS	<10W, <0.5W IN STANDBY	QUICK START SHEET, USER MANUAL (210 x 145mm, 16pp)	220 x 135 x 40, CVBS OUTPUT CABLE.	OPERATES FROM 230VAC ONLY. QUICK START SHEET & USER MANUAL CAN BE DOWNLOADED IN PDF FORM FROM www.teac.com.au
√	√	√	√	√	—	<8W, <1W IN STANDBY	USER MANUAL (145 x 105mm, 22pp)	125 x 110 x 32, CVBS OUTPUT CABLE	OPERATES FROM 230VAC ONLY. USER MANUAL CAN BE DOWNLOADED IN PDF FORM FROM www.laserco.com.au

out the SRT5432's functions as a DVB-T receiver front end, a USB-based PVR or a multimedia hub. As with the other units it received all of the local broadcasts without a problem, and recorded each of the formats with a video and audio quality that was again indistinguishable from the original. It also played all of the H.264/MP4 1080p, 720p and 480p files copied to our test USB drive.

So apart from the remote control battery contact problem, its only real shortcoming is the lack of Y-Pb-Pr component video outputs, which will probably only concern you if you have an older TV which lacks an HDMI port.

It is imported by Strong Australia (**www.strong.com.au**).

Teac HDB850

The Teac HDB850 is currently available from JB HiFi stores for $59.00, imported by Teac Australia (**www.teac.com.au**). At 220 x 135 x 40mm and weighing 433g, it's almost the same size as the Digitech. Again that includes its built-in mains power supply.

It showed up only one feature in addition to those listed in the comparison table: three small buttons at the right-hand end of the front panel, duplicating the Power on/off, Up and Down arrow buttons on the remote.

As shown in the comparison table the HDB850 provides a coaxial SP/DIF digital sound output on the rear panel, as well as the Y-Pb-Pr component video outputs, HDMI output and composite AV outputs.

The HDB850's only real limitation seemed to be that it would only accept USB 2.0 drives with either the FAT32 or FAT16 formats – not with the NTFS format.

Again there were no problems at all when we tried out the HDB850's functions as a DVB-T receiver front end, a USB-based PVR or a multimedia hub. It received and recorded all of the local broadcasts without a problem. Video and audio quality was again indistinguishable from the original. It again played all of the H.264/MP4 1080p, 720p and 480p files on our test USB drive as well.

Laser STB-6000

The Laser STB-6000 is currently available from Big-W stores for only $28.00, making it by far the cheapest of the five STBs. Imported by Laser Corporation Pty Ltd of North Ryde in NSW (**www.laserco.com.au**), it's only slightly larger than the Dynalink – measuring only 125 x 110 x 32mm and weighing a mere 164g. This is despite the fact that it has an inbuilt mains power supply.

The STB-6000 does lack a few of the features found on the others. There are no component video outputs, no SP/DIF digital audio output, no four-digit LED display on the front panel and no buttons on the front panel either.

But it's not surprising with a price tag about half that of all the others.

Despite this lack of frills, there were no problems at all when we tried out the STB-6000's functions as a DVB-T receiver front end, a USB-based PVR or a multimedia hub. It received and recorded all of the local broadcasts without a problem and also played all of the H.264/MP4 1080p, 720p and 480p files copied to our test USB drive.

Summarising

So what conclusions can be drawn from this comparison of the five HDTVB-T set-top boxes? It's clear that all five are capable of excellent performance, both as DVB-T receiver 'front ends' and as recording and replay devices for the SD and HD DVB-T programs currently being broadcast in Australia.

All but the Dynalink unit are also very good at playing a large number of multimedia file formats downloadable from the internet, including MP4/H.264 1080p high-definition movie files. And the Dynalink is pretty good at this, just a bit finicky when it comes to a small number of file formats.

If all you really want is a bare-bones unit at the lowest possible price, the Laser STB-6000 would be the way to go. But if you want as many of the extra features as possible combined with the best value for money, you probably have to choose between the Digitech XC4929 and the Teac HDB850, or perhaps the Strong SRT5432 if you don't need the component video outputs. Finally if you want to "go bush" and power your box from 12V DC, go for the Dynalink A2809 and put up with its minor shortcomings. SC

Vintage Radio

By Associate Professor Graham Parslow

Pye 1951 5-Valve Model APJ-Modified

Pye's 1951 Model APJ-Modified is a conventional post-war receiver featuring three shortwave bands, a 5-valve superhet circuit and a cut-price timber cabinet. It also has a trap for the unwary – an output transformer frame that's connected directly to the HT from the rectifier!

THE MODEL APJ Modified was one of Pye's first Australian-built radios. Manufactured in 1951, it reflects the shortages imposed by World War 2 on Australian society at the time.

The first thing you notice is that the simple timber case is made of 5-ply timber. In this respect, contemporary timber cabinet Astors and STC radios both had similar minimalist construction techniques during the early 1950s. The veneered cabinets have character but they don't really compare to the high-quality timber cabinets seen on pre-war radios.

Pye's model APJ is some 520mm wide, so it is quite a large mantel radio. It uses a fairly standard superhet circuit with a proven valve line-up and the only two real advances incorporated into the radio for the time are a thermo-mouldable plastic surround (ie, not Bakelite) and a 6AV6 miniature valve.

As well as tuning the standard broadcast band, this radio also covers three shortwave bands and the dial shows the wavelengths on which major European world services could be heard. The colours on the dial conveniently correspond with the colour-coded wave change switch on the side of the radio, making it easy to select the desired band.

This was a time when "new Australians" from Europe were keen to maintain contact with their country of birth, so shortwave listening was popular. This pastime has now virtually ceased, as the internet and other media services have made shortwave services an anachronism. As revealed later, I accidentally confirmed just how little of the shortwave spectrum is now used for transmissions.

Circuit details

Fig.1 shows the circuit details of Pye's Model APJ Modified, as detailed in the Australian Official Radio Service Manual (AORSM) of 1951. As can be seen, the front-end is rather densely packed with the band-change coils and selection switches. The mixer-oscillator valve (6J8G) is at the core of all these circuits and provides a 455kHz IF signal which is then fed via the IF transformer (53) to an IF amplifier stage based on a 6U7G. There is no tuned RF amplification, so only a 2-gang tuning capacitor is required.

This is the "modified" version of the circuit but that doesn't reflect a later improvement to the original circuit. Instead, it's a reflection of the early 1950s when many commodities were in short supply. This was a time when bricks and cement were rationed for new home builders. Similarly, some valve types were hard to obtain.

The unmodified front-end circuit is shown in Fig.2 and this features a miniature 6AN7 valve as the converter. The Pye service notes state that "it was intended to use a converter valve type 6AN7 in the model APJ receiver. As supplies of this valve were not available at the time of production, a type

Warning High Voltages!

Note that the output transformer in this set is mounted on an insulated stand-off from the chassis and its exposed metal frame is connected to the full HT voltage.

6J8 or 6J8A converter valve was used".

The 6J8 used in the radio described here is a conventional octal valve with a grid terminal at the top. The valve is fitted with an earthed goat shield to keep it stable and reduce interference; it was referred to as a goat shield, because it was made by a company called Goat Radio Tube Inc in the USA.

The service notes offer the following information: "the alterations made to use the 6J8 are as follows: (A) 60,000 Ohm resistor number 41 changes to 30,000 Ohms 1 watt and becomes number 69. (B) 6pF condenser 68 is deleted. (C) 4pF condenser 67 is deleted. (D) 200 Ohm resistor 47 changes to 200 Ohms 1/2 Watt and becomes component 70. (E) A valve shield part PN217 is required and a valve shield earth clip. (F) The 9-pin socket is changed to an 8-pin socket part PM532. (G) A grid clip part 873/495 is required for the 6J8 control grid".

The octal 6U7 IF amplifier that follows the 6J8 also has a close fitting goat shield. The 6U7 in this radio had a broken octal locating spigot. Fortunately, the earth-contact strap for the shield clearly indicates pin 1.

The amplified IF signal from the 6U7G is fed via a second IF transformer (54) to a 6AV6 double-diode triode valve. This valve is fitted to a 7-pin socket which in turn is attached to the chassis using an adapter that fits a hole punched for an octal valve. It is clear from the high number of punched holes in the APJ's chassis that this chassis was used as a platform for a range of products. In this set though, "APJ-846" is stamped into the chassis adjacent to the 6AV6 socket to aid identification.

The 7-pin miniature 6AV6 has three functions: (1) it acts as a detector to recover the audio signal from the IF signal, (2) it rectifies the IF to produce an AGC signal and (3) the triode section acts as an audio preamplifier stage. The valve is supplied with a simple slip-on metal shield that's earthed with copper braid.

The recovered audio from the 6AV6's detector is fed to a 6V6G audio output valve. This is a large octal valve that was used in the majority of Australian radios from the late 1930s until the 1950s. It was also made as the physically more compact 6V6GT.

The 6V6 is designated as a beam-power tetrode and was introduced by Ken-Rad in 1936. It was later super-

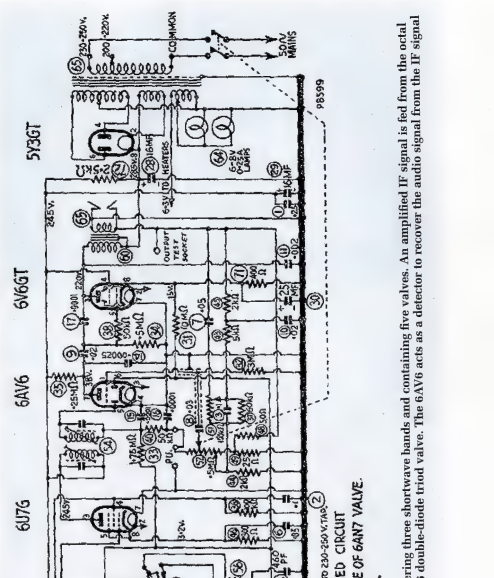
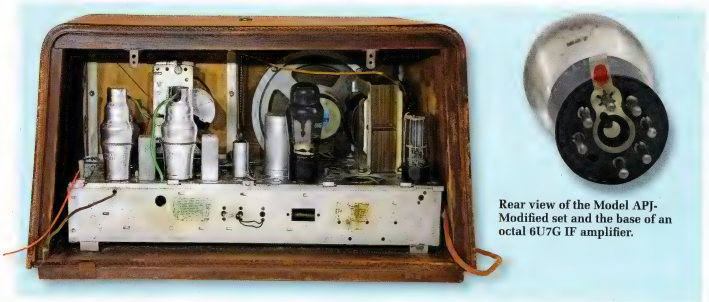


Fig.1: Pye's Model APJ-Modified set is a superhet design covering three shortwave bands and containing five valves. An amplified IF signal is fed from the octal 6U7 valve to an IF transformer (54) and then to a 7-pin 6AV6 double-diode triod valve. The 6AV6 acts as a detector to recover the audio signal from the IF signal which is then fed to the 6V6G audio output valve.



Rear view of the Model APJ-Modified set and the base of an octal 6U7G IF amplifier.

seded in the 1950s by the 6AQ5 (Mullard-Philips EL90), a miniature 7-pin valve with ratings virtually identical to the 6V6.

Although both variants of the APJ model had a primary HT of 285V, the modified variant changed the 6V6 cathode bias resistor from 300Ω to 400Ω to generate a higher negative grid bias. The presumably better placed the valve in its linear response range for less distortion. Certainly, this radio was capable of delivering a high volume with good fidelity.

An additional change for component economy in the modified APJ was to replace component 61, a 14 Henry 80mA choke, with two 5kΩ resistors in parallel. The radio featured here has these resistors and these would be much cheaper than using a choke to help filter the HT from the 5Y3GT rectifier valve.

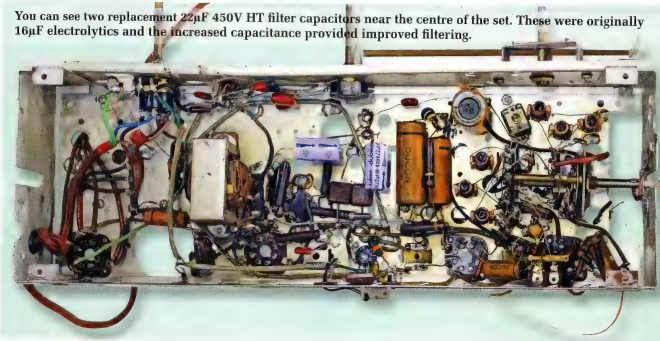
In this radio, a previous owner had replaced the two HT filter electrolytics. Both are specified as 16μF types on the circuit and both were housed in the same can on the top of the chassis. The replacement capacitors were 22μF 450V types and although the choke was absent (having been replaced with the resistors) the filtering was effective because hum was negligible.

Fortunately, the original capacitors had simply been disconnected from the circuit and the can left in place adjacent to the 6V6 output valve. The new capacitors were simply wired into place underneath the chassis.

The rectifier valve in this radio is a 5V4, rather than a 5Y3 as shown on the circuit. The 5V4 is pin-compatible with the 5Y3 but has less internal resistance. The circuit diagram indicates that the HT (high-tension voltage) from the rectifier should be 285V DC but with a 5V4 in place, the measured HT was 329V. The radio was designed for a 230VAC supply, so the higher 240VAC mains at my house also contributed to the elevated HT.

Inserting a 1.5kΩ 5W resistor in series with pin 8 of the 5V4 brought the HT back to a more reasonable 280V.

You can see two replacement 22μF 450V HT filter capacitors near the centre of the set. These were originally 16μF electrolytics and the increased capacitance provided improved filtering.



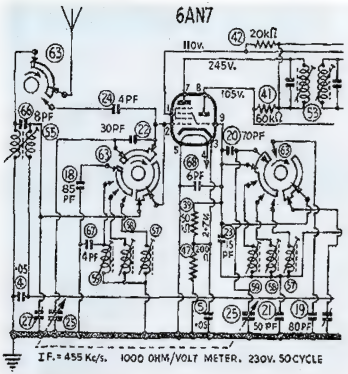


Fig.2: a 6AN7 converter valve was originally meant to be used, but due to a shortage of this type of valve during production, a 6J8 or 6J8A converter valve was used instead.

A particular problem in this set is that the HT from the rectifier and the secondary of the output transformer were connected to its frame, which was insulated from the chassis. This particular set also had excessive HT of 329V which caused occasional arcing between the output transformer primary and the earthed secondary.

This also eliminated occasional arcing (induced by the overvoltage) that could be seen as flashes between the output transformer primary (at full HT) and the earthed secondary.

And here a word of warning! If you come across one of these radios, note that the output transformer is mounted on an insulated stand-off from the chassis and its exposed metal frame is connected to the full HT (see Fig.1). The manufacturer provides no specific warning of the extreme danger, although a decal on the chassis does give a general warning as to the presence of high voltages.

So why was the output transformer's frame connected to the HT? The reason is that connecting the transformer's frame to its primary (and thus to the HT from the rectifier) helps prevent electrolytic spot corrosion of the fine wire used in the winding.

Chassis restoration

Superficially at least, the radio looked reasonably serviceable as it came to me. The speaker had obviously been replaced at some time in the past, because the Plessey brand did not appear until the 1960s, well after the set had been manufactured. The replacement speaker was also a twin-cone type which made it all the better for quality though not authenticity.

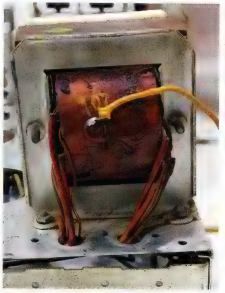
A couple of problems were also immediately evident. First, the wiring to the grid cap of the 6U7 was in rather a poor state and would have to be replaced. In addition, the external insulation on the mains transformer had broken away, exposing the low-voltage filament windings.

Removing the chassis exposed further problems. The first thing I noticed was that it was covered in a uniform brown staining that was particularly evident on the plates of the tuning gang. This radio had obviously spent quite some time absorbing nicotine in a household of smokers.

The nicotine staining was so pervasive and intractable to mild cleaning that it was a job for degreaser. First, the valves were removed, the loudspeaker detached and the mains transformer water-protected by covering it with plastic wrap. The chassis was then judiciously sprayed with degreaser, brushed clean with water and thoroughly dried with compressed air.

The plates of the tuning gang emerged from this process positively gleaming. Many corrosion spots were then removed from the steel chassis by scouring with steel wool, taking care to blow debris away. The speaker was kept well away during this process, as iron particles will attach themselves tenaciously to speaker magnets.

Looking under the chassis revealed that most of the original paper capacitors had already been replaced, so that was a good start. One paper capacitor still in place was the 0.05µF cathode bypass on the 6U7 valve. Unfortunately, it



The outer insulation on the mains transformer was broken exposing some of the low voltage windings.

A Brief History Of Pye

The "Pye-Unicam" brand first became familiar to me from the 1960s when it was encountered on high-quality laboratory equipment, particularly spectrophotometers. "Pye" is a family name, while "Unicam" is a contraction of The University of Cambridge.

W. G. Pye & Co Ltd was founded in 1896 by William George Pye, an employee of the Cavendish Laboratory at Cambridge, as a part-time business making scientific instruments. By developing a line of thermionic valves during WW1, Pye was among the first to manufacture a radio receiver for the first UK broadcasts made by the British Broadcasting Company in 1922.

In Australia, Pye opened a large factory in Clayton (Melbourne) in 1950 and specialised in 2-way radio communications equipment. Domestic radios were a less important line and it is probable that they were made in a separate factory in Abbortsford, Melbourne (perhaps a reader could provide some definitive information on the radio manufacturing site).

Continued diversification and Asian competition eventually led to Pye becoming unprofitable. From 1966, the company was progressively taken over by Philips, who still use the Pye brand for niche audio products. This has made Pye one of the longest surviving brands in the field of electronics.

Pye Australia building at Clayton; image courtesy of Kevin Poulter
www.pyetelecomhistory.org/comphist/australia-part1.html

blocked access to the lead to the 6U7's grid cap. Removing it allowed the grid cap lead to be replaced, after which the capacitor was replaced with a modern equivalent. Any remaining paper capacitors were also replaced.

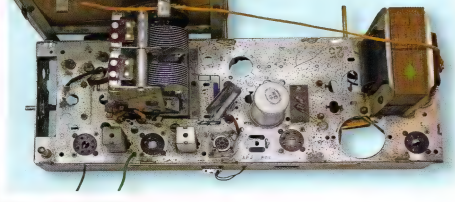
Next, I removed the knot restraining the mains cord and fitted a proper chassis clamp. I then powered the set up and with no valves in place, it consumed 7W. What's more, the two dial lamps lit up as expected and the transformer remained cool, so the initial indications were promising.

It's interesting to note that the dial lamps are powered from a 5.9VAC tap on the 6.3VAC filament winding. The lamps themselves are specified as 6-8V types, so operating them at 5.9VAC should result in good lamp life. Although nominally 6.3VAC, the measured filament voltage was in fact 6.5VAC, no doubt due to the fact that the set was originally designed for a 230VAC input.

At this point, the valves were installed, the speaker reconnected and the set powered up again. I was optimistic that it would work but unfortunately, I was unable to tune any stations and only crackling noises came from the speaker.

Some gentle prodding soon pointed to the 6AV6 valve as the source of the crackling. It was making intermittent contact with its socket and after cleaning the valve pins the crackle went away. However, I was still unable to tune any stations across the band.

It was then that I realised that the wave-change selector switch was set to the lowest of the shortwave bands. I rotated the switch to the broadcast band and the set came to life. It performed quite well, the only problem being intermittent changes in the volume. This problem was quickly traced to a dry joint in the negative feedback connection at the output transformer's secondary and fixed.



The cleaned chassis without any of the valves attached, a degreaser was used to remove the nicotine stains from the set.

Restoring the cabinet

Over the years, heat from the valves had cracked the lacquer applied to the cabinet, indicating that this set had had a long service life. To fix this, the timber was sanded back to remove all traces of lacquer, after which a light oak stain was applied to give more character to an otherwise bland appearance. The exposed edge of the plywood used for the face board was then painted black.

Several coats of satin-finish polyurethane were then sprayed on, with light sanding between coats. Then an enamel Pye badge was fixed to the top of the cabinet to replace the Pye decal lost by sanding.

Finally, the knobs had silver paint brushed into their individually etched labels for volume, tone and tuning. And that was it – the set is a good performer and has been added to my collection. SC

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Problem with 8-digit Frequency Meter

I was hoping for some advice on how to correct a failed attempt at building the 8-digit Frequency Meter from the August 2016 issue. When I apply power, the LCD illuminates with the top row as all blocks and no text on the second row. Pressing the momentary switches has no effect, nor does applying a signal to the BNC input.

I have done all of the usual checks: I tested every component before installation and followed the instructions implicitly. I have verified the 5V rail and adjusted VR1 for 2.5V (although I am aware that this would be inconsequential to the LCD display). I have tested all of the LCD contacts for connectivity to the PCB and eliminated the possibility of short circuits.

I did install the PIC with the correct orientation but noticed while troubleshooting that the angled tabs on the back of the metal casing of the LCD may have contacted pin 9. I cannot see how this could have caused any grief. I also noticed, upon removal from the conductive packaging foam, that the PIC had a couple of pins bent in a "c" shape. I assume they are tested prior to dispatch. (I am grasping at straws here!)

I don't have the means to test the integrity of the PIC program. I am just wondering is there anything I am missing prior to ordering a replacement microcontroller chip? I don't think I am a complete klutz as I have successfully built the 12-digit meter from the January 2013 issue and the 50Mhz counter from the October 2003 issue.

Any assistance would be greatly appreciated. (S. S., Zillmere, Qld)

- The rows of blocks on the LCD suggests that the module is not being driven correctly, either through no connection or a short between the data lines D7, D6, D5 and D4 and the RS and enable of the LCD module. Check that pins 5, 7, 8, 9 and 10 on the LCD are all connected to circuit 0V (GND).

Also, check the continuity from pin 13 of IC5 to pin 14 of the LCD, pin 12 of IC5 to pin 13 of the LCD, pin 11 of IC5 to pin 12 of the LCD, pin 10 of IC5 to pin 11 of the LCD, pin 18 of IC5 to pin 4 of the LCD and pin 17 of IC5 to pin 6 of the LCD.

Check for any shorts between these pins and check the solder connections to the pin header on the PCB and the socket strip on the LCD module.

Other possible causes of this type of problem are that IC5 isn't being supplied with 5V, pin 4 is not at 5V and that the crystal oscillator is not running. Check IC5 for 0V and 5V at pins 5 and 14 respectively, check pin 4's voltage and if possible, verify that the crystal oscillator is operating.

If those checks don't turn up any problems, suspicion must rest on the microcontroller either being faulty or it is not programmed correctly.

We normally verify the programming of all chips before we supply them however your comment about the micro's pins being bent is a concern.

We use a ZIF socket for programming DIP micros and normally supply them pushed into anti-static foam so the pins should not be bent. As you purchased the micro from us, if all checks suggest that it is faulty, contact us for a replacement.

Editor's note: it turns out that this fault was due to the fact that several slightly different LCD screens can be used for this project and the firmware LCD initialisation routine did not work correctly with all of them. Revision B firmware is now available (and supplied with all PICs sold from now on) which addresses this.

Adjusting Tempmaster Mk2 temperature

I am using the Tempmaster Mk2 Electronic Thermostat from the February 2009 issue to convert an old fridge to a wine cooler. It works fine except that the temperature setting is too low and I want to raise it by around 9°C to achieve a fridge temperature of around 16°C.

I understand that to do this I need to adjust trimpot VR1 using a small screwdriver. However, I would like to know whether I need to turn it clockwise or anticlockwise to raise the temperature to avoid a lot of trial and error. (G. M., Hughesdale, Vic)

- If you have a look at the circuit of Fig.1, the cooling configuration, increasing the resistance of VR1 will raise the temperature so you can use a multimeter to measure its resistance

Temperature Control with the Universal Temperature Alarm

Your Universal Temperature Alarm project in the July 2016 issue is something I could use to keep control of the temperature in my workshop.

When I want to use two-pack paint on an old car I'm restoring, the paint manufacturer recommends close control over temperature. Temperature can vary considerably from minute to minute here in the Southern Highlands, especially in winter!

It's a pity John Clarke did not allow for a small relay to control a larger external one to switch a heater, fan or whatever. Is it possible to add a small relay, perhaps parallel to the High LED or the Low LED or both, to control external equipment? (H. M., Bowral, NSW)

- It seems that our Tempmaster Mk.3 project from the August 2014 issue would be a better match for your application. It is available as a kit from Jaycar (Cat KC5529) or we can supply the PCB for the project – see www.siliconchip.com.au/Shop/8/2786

while you twiddle the adjustment to confirm. Normally, the pot would be fitted so that clockwise rotation increases the temperature however to be 100% sure, you should check that clockwise rotation does increase the resistance between its terminals at either end.

Having said that, 16°C seems a bit high for wine storage, especially white wines.

Guitar preamp buzz on balanced line outputs

I have recently completed two of the 2-Channel Guitar Preamplifier units (SILICON CHIP, November & December 2000) and at present one is being used for a guitar and the other for a keyboard.

After constructing both units and going through the preliminary testing requirements, both units produced the expected voltages. Upon connecting both to separate inputs on a mixing desk and an amplifier, I found that both units worked perfectly when used with the unbalanced line output. The output signal was very clear and no other noises were noted.

However, connecting the balanced line output to the mixing desk resulted in a loud buzzing noise and an exceptionally loud output signal which had to be reduced to basically zero on the units' channel input pot, VR1. The channel input pot then gave virtually no control over the actual volume on both units.

My understanding is that the channel input pot (VR1) controls the channel input signal level and the volume control (VR5) controls the unbalanced line output signal level.

With the balanced output signal level, I believe the balanced line is controlled just by the channel input control (VR1) with VR5 having no effect at all.

I think the buzzing noise may be caused by a balanced signal earthing problem but I don't understand why I can't adjust the volume properly. Your thoughts would be greatly appreciated as I would like to be able to connect the balanced line output to the mixer without the buzzing noise/input level problems. (D. W., Alexandra Hills, Qld)

- The high signal level from the balanced output is the same level as that from the unbalanced output when VR5 is at maximum. That level is line level, at around 770mV to 1V RMS. On a sound mixing desk, the balanced inputs are usually set up for microphone signal levels which are only about 10-50mV RMS.

There should be an attenuator for the balanced input on the mixing desk to accommodate the higher signal, activated with either a pushbutton switch or rotary control.

For unbalanced inputs on a sound desk mixer, the input is usually set up for line levels (770mV to 1V). That would be why the levels appear to be so different between using a balanced and unbalanced signal from the guitar preamp to the mixing desk.

To reduce the balanced level, you could attenuate the signal in a similar way as VR5 but using a dual gang pot to attenuate both output signals. Or connect pin 3 of IC4d to pin 5 of IC4b and remove the 220nF (0.22µF) capacitor at pin 5. That will allow VR5 to reduce the balanced level as well as the unbalanced level.

The hum with balanced connections could just be due to the highly amplified signal. The same earth is used for balanced and unbalanced connections so if it was the earth, then it should be producing hum for the unbalanced connection as well.

However, if reducing the balanced output level does not cure the hum, you may need to disconnect the pin 1 earth from the balanced output XLR connector. Alternatively, there may be an open circuit connection for one of the balanced signals in the XLR lead used to connect the guitar preamplifier balanced output to the mixing desk.

Using USB Data Logger with Windows 10

I purchased the Digital/Analog USB Data Logger, published in December 2010, by Mauro Grassi. The device is part of an on-going project which I have not yet completed. Initially I connected it to my Windows XP PC however the PC no longer runs and I was forced to upgrade to Windows 10. The USB drivers for the device will not load on my Windows 10 PC. I get the following message:

"Windows found driver software for your device but encountered a error while attempting to install it."

"The third party INF does not contain digital signature information." (C. J., Parkinson, Qld)

- We haven't tried the USB Data Logger on Windows 10. As it is a 2010 design, there's no guarantee it will work, however we think it might.

Based on the error message you've quoted, you will need to enable the ability to install unsigned drivers before it will have a chance to work. You can find information on how to do that here:

http://acer.custhelp.com/app/answers/detail/a_id/38289/~/windows-10%3A-disable-signed-driver-enforcement

By the way, you might want to check whether it will work without installing drivers. Many USB devices which required drivers to be installed in earlier versions of Windows now work without them in Windows 10, as it incorporates some automatic USB serial interface detection.

Cutting grooves for the Currawong cabinet

The Currawong Stereo Valve Amplifier project (November 2014-January 2015) calls for a 2mm-wide groove, 9mm deep in the timber cabinet.

I have scoured the internet and the closest router bit I can find is 2mm wide with a 1/4" shank which will only give a maximum depth of 4.8mm. The minimum diameter cut for a Dremel router bit is 3.17mm. So what type of router bit did you use for this project? (B. P., Tea Tree Gully, SA)

- We used a 2mm router bit that which was able to cut to a depth of 9mm. If you can only cut to 4.8mm, use a tenon saw to carefully increase the depth of the groove. Alternatively, use a slightly larger diameter router bit, up to say 2.5mm.

No over-temp alarm in Cooling System Monitor

The heading for the Arduino-based Cooling System Monitor article in the June 2016 issue says "It monitors the speed of the fans, the water flow and temperature and sounds an alarm in the event of a malfunction..."

Problems getting SemTest display to work

I am hoping you can offer me some help with the Semtest published in 2012. I have built this project and I am having some problems. At power up, the unit has no text display other than the boxes on the display panel which can be revealed by increasing the contrast. The backlight on the display is also operating.

I have verified the connectivity of the three ribbon cables by point to point continuity testing. The voltages on REG1 are correct. The voltages marked on the circuit on both upper and lower PCBs all appear to be correct and VR2 has been adjusted to supply 2.49V to the micro. I have established that the crystal is oscillating at pin 14 of the micro.

None of the pushbuttons has any effect on the display. I am powering the unit from a bench supply which indicates that the unit is drawing less than 100mA. I have a reasonable degree of confidence that I have correctly installed the componentry and that there are no solder faults. Can you suggest a troubleshooting approach? As always, your help will be greatly appreciated. (B. D., Hope Valley, SA)

● The boxes on your display are the 5x7 pixel dot matrices, which normally each display one ASCII character. It sounds like no characters are displayed and you have turned up the contrast far enough to reveal these matrices as black rectangles. This suggests that either the software on the micro is not running or if it is, its data output is not reaching the LCD module.

The first thing to check would be that the PIC16F877A has been properly programmed. Since it seems you purchased it from SILICON CHIP, we are assuming it has been.

Since you have checked all of the main voltages on both boards, verified that the micro's crystal oscillator is working, and also checked the three interconnecting ribbon cables for continuity, there seems to be not much left to explain the unit's non operation. As such, you will probably need an oscilloscope to track the problem down.

If the micro is sending text to the LCD (as it should be), you should be able to find a string of two microsecond wide positive-going pulses (of around 5V peak-to-peak) appearing on the EN line. This is the line coming from pin 8 of the micro (IC4) to pin 3 of CON2, and then passing up via the smaller ribbon cable to pin 3 of CON5 on the upper PCB, and finally to pin 6 of the LCD.

These pulses are sent by the micro to direct the display controller to accept another character for display, so soon after power is first applied to the SemTest circuit, there should be a series of 32 of these pulses sent up via the EN line to get the display controller to accept the 32 characters (2 lines of 16) making up the initial greeting message screen ("SC Discrete Semi" + "conductor Tester").

So if your scope shows these pulses present on the EN line within a couple of seconds after power-up, this will be a pretty good indication that the problem is not due to the micro and may be the result of a problem with the display itself.

It would be a good idea to use your scope to make sure these pulses are making their way right up to pin 6 of the LCD. If they are, this will also rule out a problem with the ribbon cable and its connectors on the two PCBs. If they're present at pin 8 of the micro but not reaching pin 6 of the display, this will indicate a problem with the cable and its connectors.

Incidentally, we have heard of problems caused by IDC ribbon cable connectors, sometimes due to bad crimp connections between the ribbon cable conductors and the plug pin tails, and sometimes due to dry joints where the socket pin tails are soldered to the PCB pads underneath. So check for these possible problems very carefully if you do find that the EN pulses are not getting to pin 6 of the display.

Even if the EN pulses are getting through to the display, it's still possible that your problem may be due to a bad connection on one of the other lines to the display. For example, there might be a break in the RS line (pin 9 of the micro to display pin 4), or in one of the four data bit lines (pins 15-18 of the micro, pins 11-14 of the display).

But these won't be as easy to check with your scope, because they are a bit more complex. Ideally you'd need to check the signals on each line at both ends – to compare the waveforms and see if they match. This would be easiest done with a 2-channel scope.

As far as I can see is it won't generate an alarm if the temperature rises too high. Correct me if I'm wrong. Should it sense the water temperature? What if the air flow is blocked and the operator is asleep? (R. W., Mount Eliza, Vic)

● It only monitors temperature in the sense that it is displayed; it will not trigger an alarm. It would not be terribly difficult to modify the software to sound an alarm on over-temperature. You would just need to use an analog input and check if the voltage is over or under a particular threshold, depending on how the temperature sensor is driven.

In our case, we don't think there is much chance that the air flow could get blocked and so decided it wasn't worth the bother to make extra connections to the temperature sensor, running the wiring up to the Arduino module and figuring out the relationship between voltage and temperature.

The laser tube won't be destroyed as long as the water continues to flow (after all, it survived running for several weeks with no radiator at all). In the worst case, it will affect the quality of the cutting until the job finishes and the operator realises that there is a problem.

In a more critical situation such as an automotive radiator you would probably wire up the temperature sensor to generate an alarm.

The Arduino software already includes code to read an analog input (the fan speed control pot) so it should not be a difficult job.

Replacing faded LEDs in the LED Superclock

I built the Mesmeriser LED Clock (June 2005), also known as the LED Superclock or Clock Watcher's Clock, when it first came out and it has been

Solar tracking and water level measurement

I have just installed a solar bore on my property and thought it would be great if it could track the Sun. The mounting system could be adapted but I cannot find any kits online to do this.

Can you advise if SILICON CHIP has published a suitable circuit? If not, can you add it to your list as solar power is such a great free energy source. Getting more out of the panels can only make it more useful.

I am also looking at finding a way to indicate the standing and dynamic water level in my bore to ensure I do not exceed its capacity. I was looking at the Tank Water Level Indicator article by Allan March in the July 2007 issue of SILICON CHIP. Do you have another one that you could recommend? (R. N., Rathdowney, Qld)

- We have published several solar tracker circuits as shown below:

January 2012, Circuit Notebook: Solar Tracker Employs Two Photo Cells, by Herman Nacinovich.

November 1995, Circuit Notebook: Simple Solar Tracker, by R. Josey.

January 1995: Build A Sun Tracker For Solar Panels, by Nenad Stojadinovic.

And yes, the Water Level Meter from the July 2007 issue should be suitable.

running non-stop ever since. The only problem now is that the red LEDs are not the same brightness any more.

The one at the one second mark is lit up nearly all the time (and fairly dull by now) while the one at the 59-second mark is only on very briefly and therefore still as bright as the day it was assembled.

I was thinking of replacing all the LEDs to get a uniform brightness again but I'm not sure how feasible it would be due to the plated-through holes in the PCB. The second option would be to get a new PCB (if they are still available) and then reuse the ICs, etc, as it wouldn't be as much work as replacing all the LEDs.

The third option would be to buy a whole new kit and start again, but it seems they are no longer available from Jaycar. Any thoughts or suggestions would be very much appreciated. (T. N., Carter's Ridge, Qld)

- It is a bit disappointing that the LEDs have faded. Unfortunately, the kit and PCB is no longer available so the only practical approach is to replace the LEDs.

It should be relatively easy to get the LEDs out and then clear the holes with a solder sucker; simply heat both pads and gently pull the LED out before clearing the holes individually.

If you cannot clear some of the holes, it might be necessary to drill them out with the smallest possible drill and then it may be necessary to solder the LED legs on both sides of the PCB, but that's unlikely.

Replacing the LEDs would be much easier than moving the ICs to another PCB as the LEDs are only soldered to two pads each while the ICs have many more pins.

Questions about MPPT Charge Controller

I was reading your article on the 12/24V 3-stage MPPT Solar Charge Controller from the March 2012 issue. It's a nice and informative article but I have few simple questions.

1) Is it a true MPPT Charge Controller?

2) Is Mosfet Q1 a linear type?

3) Is the Mosfet controlled by switching (using a PWM signal) or in a linear mode?

4) Do you have any pre-built products using this design? If so, can you supply a link?

Thank you for your informative magazine. (U.A.B., Pakistan)

- The 12/24V 3-Stage Solar Charge Controller is a genuine MPPT charge controller. The Mosfet is a switching type and is driven with a PWM signal.

An inductor is used to convert the voltage and current for maximum power transfer from the solar panel. We do not make any commercial products. You can build the charger using available parts or a kit from Jaycar (Cat. KC5500, www.jaycar.com.au).

Note, that we published a revised version of this project in the February and March 2016 issues which provides a higher charging current and greater efficiency and a revised kit is also available from Altronics (Cat. K6029, www.altronics.com.au). SILICON CHIP can also supply some of the parts for this project; see: www.siliconchip.com.au/Shop/?article=9813

Simple low-battery alarm

Having been inconvenienced by a flat car battery at home more than once, I would love a simple low battery alarm that could be direct-connected to the battery terminals, that would let out an ear-piercing sound if the battery was discharged below a threshold voltage.

Would you consider publishing a suitable circuit/kit that would activate a suitable relay? Now I don't know what voltage would be a safe threshold voltage to activate the alarm – perhaps between 10.5V and 11.5V?

But I do know that having a time delay of approximately one minute would be necessary to prevent nuisance alarms because of starting the engine. (C. D., Auckland, NZ)

- We published a couple of battery saver projects, one in July 2004 ("Versatile Micropower Battery Protector", by Peter Smith) and one in September 2013 ("LifeSaver for Lithium or SLA batteries", by Nicholas Vinen) but unfortunately, both work by disconnecting the load when the battery voltage gets low, which is not what you're asking for.

Also, neither comes close to handling the current that can be drawn from a car battery during starting.

Having said that, you could build the Battery LifeSaver and leave off Mosfet Q1, then connect a 5V piezo buzzer between the 5V output of REG1 and the output (pin 6) of IC1. The piezo would then sound when the battery voltage drops below the set threshold.

A time delay can be accomplished by drastically increasing the value of the 10nF capacitor at pin 3 of IC1; you can probably fit an SMD ceramic capacitor of up to 100µF here, which would give a time delay of a minute or two.

For a 12V lead acid battery, a good alarm point would be 11.5V but a car battery can be expected to drop below that value while cranking the engine. Keep in mind that when the piezo sounds, to warn you that the battery

voltage is low, its current draw will only speed up the battery discharging!

Replacement lamp for a projector

As you would be aware, photography has changed quite considerably over the years to an extent where it is easy to do almost anything with pictures taken with a camera.

There is one form of photography which used to be very popular and that is a very old method which produced transparencies.

This form of photography used a projector with a very bright lamp and a white screen or a white wall. In order to get a greatly enlarged picture on the screen, the projector must be placed at an optimum distance away.

Unfortunately, my projector has blown its lamp. Trying to purchase another one in Elizabeth, South Australia has proved impossible. It may be possible to use a very bright LED with its own power supply as a replacement lamp.

Has SILICON CHIP ever produced such a project? If not, are there any suggestions you may make? (G. K., Elizabeth East, SA)

● While very bright white LEDs are now available and there are some projectors which use a white LED light source, we do not know if you could successfully substitute a LED lamp for a quartz halogen projector lamp because the projector lamp and associated reflector are designed around the point source of the halogen lamp filament.

It may be possible to substitute a car LED headlamp but it could be quite difficult to adapt it for projector use.

24V DC Motor Speed Controller wanted

I have a 7.25" gauge ride-on model locomotive and am looking for a reliable speed controller.

The motor details are: 500W, 2700 RPM, permanent magnet motor. Running speed with a load of seven adults is approximately 10km/h.

The maximum motor current draw is 45A on starting and it runs off 24V (2 x 12V deep cycle batteries).

Has SILICON CHIP published a speed controller that could help me? (J. C., Marion, SA)

● We are publishing a DC motor speed controller which would be ideal for your application in this very issue. See page 36.

Trouble building Class-D amplifier kit

I have just finished building the Jaycar KC5514/5 kit for High-Power Class-D Audio Amplifier (SILICON CHIP, November & December 2012) with the recommended power supply kit (±57V).

Everything seems to be in order as I have checked several times but I keep blowing fuse F2 (5A 250V). Any advice or help would be greatly appreciated.

I also noticed a ground point on the power supply that I can't find any reference to in the instructions. I measured across the 57V rails and got 114V. I have adjusted VR1 to 850Ω. (K. S., by email)

● Make sure that all electrolytic capacitors are inserted with the correct polarity and that Q1, Q2 and Q3 are electrically isolated from the heatsink with the insulating washers and insulating bushes.

Also make sure you have ed the correct values for a +50V and -50V supply according to Table 1 on page 68 of the December 2012 issue.

The ground point you refer to may be for the mains Earth that would connect to a metal chassis if used. Or maybe you are referring to the GND PC stake on the amplifier that is for earthing to the heatsink.

GND1 is a test point for allowing voltage measurements referenced to 0V. The ground lift (LK1) is used to either break the GND connection when the jumper shunt is out out or inserted

. . . *continued on page 102*

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This remarkable collection of PDFs ***covers every issue*** of R & H, as it was known from the beginning (April 1939 – price sixpence!) right through to the final edition of R, TV & H in March 1965, before it disappeared forever with the change of name to EA.

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01/17

PRINTED CIRCUIT BOARDS

NOTE: The listings below are for the PCB only – *not a tuit kit.* If you want a kit, contact the kit suppliers advertising in this issue. For more unusual projects where kits are not available, some have specialised components available – see the list opposite.

NOTE: Not all PCBs are shown here due to space limits but the SILICON CHIP ONLINESHOP has boards going back to 2001 and beyond. For a complete list of available PCBs, back issues, etc, go to *siliconchip.com.au/shop* Prices are PCBs only, NOT COMPLETE KITS!

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
PIC/AVR PROGRAMMING ADAPTOR BOARD	JUNE 2012	24105121	$30.00
CRAZY CRICKET/FREAKY FROG	JUNE 2012	08109121	$10.00
CAPACITANCE DECADE BOX	JULY 2012	04106121	$20.00
CAPACITANCE DECADE BOX PANEL/LID	JULY 2012	04106122	$20.00
WIDEBAND OXYGEN CONTROLLER MK2	JULY 2012	05106121	$20.00
WIDEBAND OXYGEN CONTROLLER MK2 DISPLAY BOARD	JULY 2012	05106122	$10.00
SOFT STARTER FOR POWER TOOLS	JULY 2012	10107121	$10.00
DRIVEWAY SENTRY MK2	AUG 2012	03107121	$20.00
MAINS TIMER	AUG 2012	10108121	$10.00
CURRENT ADAPTOR FOR SCOPES AND DMMS	AUG 2012	04108121	$20.00
USB VIRTUAL INSTRUMENT INTERFACE	SEPT 2012	24109121	$30.00
USB VIRTUAL INSTRUMENT INT. FRONT PANEL	SEPT 2012	24109122	$30.00
BARKING DOG BLASTER	SEPT 2012	25108121	$20.00
COLOUR MAXIMITE	SEPT 2012	07109121	$20.00
SOUND EFFECTS GENERATOR	SEPT 2012	09109121	$10.00
NICK-OFF PROXIMITY ALARM	OCT 2012	03110121	$5.00
DCC REVERSE LOOP CONTROLLER	OCT 2012	09110121	$10.00
LED MUSICOLOUR	NOV 2012	16110121	$25.00
LED MUSICOLOUR Front & Rear Panels	NOV 2012	16110122	$20 per set
CLASSIC-D CLASS D AMPLIFIER MODULE	NOV 2012	01108121	$30.00
CLASSIC-D 2 CHANNEL SPEAKER PROTECTOR	NOV 2012	01108122	$10.00
HIGH ENERGY ELECTRONIC IGNITION SYSTEM	DEC 2012	05110121	$10.00
1.5kW INDUCTION MOTOR SPEED CONTROLLER (NEW V2 PCB)	DEC 2012	10105122	$35.00
THE CHROMIUM PREAMP and 7W AUDIO AMP (one PCB)	JAN 2013	01109121/2	$10.00
GARBAGE/RECYCLING BIN-REMINDER	JAN 2013	19111121	$10.00
2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD	JAN 2013	04111121	$35.00
2.5GHz DIGITAL FREQUENCY METER – DISPLAY BOARD	JAN 2013	04111122	$15.00
2.5GHz DIGITAL FREQUENCY METER – FRONT PANEL	JAN 2013	04111123	$45.00
SEISMOGRAPH MK2	FEB 2013	21102131	$20.00
MOBILE PHONE RING EXTENDER	FEB 2013	12110121	$10.00
GPS 1PPS TIMEBASE	FEB 2013	04103131	$10.00
LED TORCH DRIVER	MAR 2013	16102131	$5.00
CLASSIC DAC MAIN PCB	APR 2013	01102131	$40.00
CLASSIC DAC FRONT & REAR PANEL PCBs	APR 2013	01102132/3	$30.00
GPS USB TIMEBASE	APR 2013	04104131	$15.00
LED LADYBIRD	APR 2013	08103131	$5.00
CLASSIC-D 12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
LFHF UP CONVERTER	JUN 2013	07106131	$10.00
10-CHANNEL REMOTE CONTROL RECEIVER	JUN 2013	15106131	$15.00
IR-TO-455MHZ UHF TRANSCEIVER	JUN 2013	15106132	$7.50
"LUMP IN COAX" PORTABLE MIXER	JUN 2013	01106131	$15.00
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L'IL PULSER MKII FRONT & REAR PANELS	JULY 2013	09107132/3	$20.00/set
REVISED 10 CHANNEL REMOTE CONTROL RECEIVER	JULY 2013	15106133	$15.00
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
UHF TO INFRARED CONVERTER	JULY 2013	15107132	$10.00
IPOD CHARGER	AUG 2013	14108131	$5.00
PC BIRDIES	AUG 2013	08104131	$10.00
SIDRADIO (INTEGRATED SDR) Main PCB	AUG 2013	04107131	$10.00
SIDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (same PCB as Headphone Amp (Sept'11)	OCT 2013	01309111	$20.00
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTAPAL-D MAIN BOARDS (for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above (Nov 2012/May 2013))	JAN 2013	01113131-3	$35.00/set
LED Party Strobe (also suits Hot Wire Cutter (Dec 2010))	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
L'il Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
NICAD/NIMH BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	99106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04105141a/b	$15.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-THEREMIN MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10/SET
MINI-D AMPLIFIER	SEP 2014	01110141	$5.00

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COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (D-I) BOX	OCT 2014	23109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110131	$15.00
DUAL PHANTOM POWER SUPPLY	NOV 2014	18112141	$10.00
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
ONE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TDR DONGLE	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015		$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04104151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04106152/3	$20.00
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VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
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MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
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Flexitimer: changing values for a 5–10s interval

I have a question regarding the KA1732 Flexitimer kit I purchased from Jaycar and subsequently assembled. I don't have any BASIC programming knowledge as recommended in this kit's accompanying data sheet to help work out timing values and am seeking advice about what values I would need to change to get a delay start between 5 and 10 seconds.

I believe the components R1, RV1, R2, and C1 need to be changed. Can you please help. (G. M., via email)

● The Flexitimer Mk3 project was actually published in Electronics Australia in March 1991. According to the intro in that magazine, the original design can time "... from a few seconds to a whole day". As such, it can probably be configured for a 5-10 second interval without modifying any values.

Basically, the timing interval is determined by the frequency that IC1 is operating at, with the multiplier value selectable between 16 and 8192.

This suggests that for the sort of time interval you are talking about, you want IC1 to operate at something like 100Hz. That way you could use one of the intermediate division ratios such as 512 or 1024 to get your 5-to-10 second delay.

To set IC1 to 100Hz, you can refer to figure 3 on page 7 of the LM555CN data sheet. We have a timing resistance of around 470kΩ ohms, set by R2.

If you follow the line on that chart for 1MΩ, you will see that a 10ms period (ie, 100Hz) is achieved with a capacitance of just over 10nF. Double this to 22nF for 470kΩ. That would be a reasonable value for C1.

So with C1 = 22nF and R4 connected to say pin 12 of IC2 (ie, Q9), you can check the resulting timing interval with a stopwatch or clock and then adjust either the linking option or trimpot RV1 to get the interval into your desired range.

Ask SILICON CHIP

. . . continued from page 99

when necessary to prevent hum.

Low-ESR capacitors for Ultra-LD Mk.4

I am in the process of building several of your Ultra-LD Mk.4 amplifier modules, as featured in the July, August and September 2015 issues. Neither Jaycar nor Altronics seem to carry the specified (optional) 1000μF 63V low-ESR electrolytic capacitors which can be fitted to the amplifier board.

I note that they use a pin spacing of approximately 7.5mm and a can diameter of around 16mm but I can't read any brand or type markings on the capacitors in the photos. Can you please tell me where you got these capacitors from? (B. C., Carrum Downs, Vic)

● Those are United Chemi-con EKZE630ELL102MLP1S low-ESR capacitors sourced from Digi-Key, part code 565-1729-ND. They are rated for 5000 hours life at 105°C with a typical impedance of just 19mΩ and are quite reasonably priced at around $2 each.

Since those capacitors are not terribly critical to the operation of the amplifier module, with the high-frequency ceramic SMD bypass capacitors providing sufficient stability, you could use Jaycar RE6236 or Altronics R5188 instead.

Neither are rated as low-ESR but they have reasonable ripple current ratings of around 1A each, albeit not as good as the United Chemi-con types, at 1.74A.

Making your own cruise control

Have you ever published a circuit on how to make your own cruise control for a motor vehicle? (J. & T., via email)

● We haven't published a recent cruise control project. There are many after-market cruse control kits available from auto accessory shops that would suit your car.

These include professional controls that match your vehicle and are designed for the particular vehicle and whether it has a cable-driven throttle or electronic throttle.

Designing an ignition system can be tricky

I recently bought the November and December 2012 back issues of SILICON CHIP, along with a PCB, with the intention of building the High Energy Electronic Ignition System.

When I read the article, I realised there were certain features I could do without, so I decided I would build the project, leaving out the dwell adjustment, battery level monitoring and the FOLLOW option.

By the time I had eliminated the features that I didn't require, I found myself basically looking at a microcontroller (with its oscillator and power supply circuit), an IGBT and a trigger input circuit.

I realised that this could easily be done with an RBBB Arduino board, as shown at: www.siliconchip.com.au/l/aaao

I decided to use the Arduino purely because I can program it to suit my own individual requirements with regards to a mapped advance curve. I then set about building a hybrid of your design, using the Arduino at the heart of the circuit. I used the IGBT and voltage regulator from the SILICON CHIP design and very quickly had everything put together and operating on my bench.

I am using a Hall effect sensor with the open collector pulled high and triggering on the falling edge when the magnet triggers the sensor. But I found that I had to do quite a lot of fiddling about in order to make the system run stably. It suffers badly from interference. I found that I had to use a screened cable from my Hall sensor up my circuit board and a resistor spark plug. If I omit either of these, the whole thing goes totally berserk.

I am just a bit perplexed how other circuits (such as yours) can manage to live with such high frequency interference. I have everything inside a shielded enclosure and I'm even a bit concerned that on the race start line, another neighbouring competitor's system (where no resistor plugs are used) might be enough to scramble my own ignition.

Can you think why this system may be so fragile? Are there any fundamental flaws in what I have done, considering

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it is not so very different from your design? (N. M., Northern Ireland)

● Some microcontrollers are much more susceptible to interference than others. For the Hall Effect input, maybe a low-value filter capacitor would remove glitches. Connect a 10nF capacitor between Hall Effect output and ground (assuming a 10kΩ pull-up resistor). Also, the supply to the Hall Effect unit should be filtered with a 100Ω resistor and filter capacitor (100µF). Make sure the microcontroller supply is filtered well with 100nF capacitor across supply pins.

We are not aware of how you programmed the Arduino. Dwell needs to be the period that the coil is energised, but with a fixed delay before the next predicted firing. So a period counter is required to continuously count the period between each firing and then to start to charge the coil so that firing occurs after the dwell period at the next firing point.

So the dwell starts before the next spark as predicted by the period counter. The period counter is updated on every firing so as to keep up with RPM changes.

Often when programming, you can develop this in stages starting with maximum dwell, then firing for a fixed period (1ms) before the coil is re-energised. The coil needs protection from

burning out by using a ballast resistor. Then add in the dwell feature that starts to charge the coil a fixed period before firing.

Note that if the RPM is high, the full dwell period may not be available as there isn't the time to fit in firing and the full dwell period before the next firing. You need to have a minimum firing period so that the dwell period will not reduce spark duration at high RPM.

Can SiDRADIO be used with the Raspbery pi?

Can I use the DVB-T dongle, as featured in the SiDRADIO project (October-November 2013) with the latest version of the Raspberry Pi? I have subscribed to Silicon Chip for seven years and it's a great magazine! (C. J., Samson, WA)

- You possibly can but bear in mind that the SiDRADIO design is based on Windows software. If you wanted to interface to the Raspberry Pi, you need to use a different software package. Unfortunately, we are not in a position to help you with this but it looks like what you are asking about has been done already; have a look at: **www.rtl-sdr.com/tag/raspberry-pi/**

ETI 601 Music Synthesiser kit

I can see from your website that you are involved in old DIY kits from ETI magazine. I'm interested in purchasing the kits or parts (eg, PCB) for an old ETI Project (601 Music Synthesiser 3600/4600: October 1973 to July 1974) about the construction of an ETI 4600 analog synthesiser. (A. G., by email)

- This was a true breakthrough project design for ETI and it has never been bettered. It is now over 40 years old and while virtually all of the electronic components should still be available, there are no PCBs and nor do we have the PCB (tape) artworks in our archive, unfortunately.

Even if the boards and metalwork were still available, building it today would be a very expensive proposition and you would be able to provide all its facilities with a much cheaper digital design you can now buy off the shelf.

However, if you want to peruse all the articles we can provide PDFs and these can be ordered from our online shop.

Error compiling the Arduino ECG software

I have downloaded the software for the Arduino-based USB ECG monitor that appeared in your October 2015 issue. The problem is that when I verify/compile the sketch, I get an error in *"Assemblyinfo.cpp"* as follows: "System is not a namespace-name".

I am running Windows 8.1 and I compiled the sketch on a computer with Windows XP with the same results. Can you help please? (J. W., via email)

- This sounds like an error with your Arduino IDE installation; *"Assemblyinfo.cpp"* is not part of our source code but it may be an internal file used by Arduino. We suggest you try installing the latest version of the Arduino IDE, in case the one you currently have installed contains an error. The latest version, at the time of writing this, is V1.6.12 and it is available as a free download. We just checked that the sketch compiles using the version we currently have installed (V1.6.7) and it completed without errors. SC

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Next Issue

The February 2017 issue is due on sale in newsagents by Monday January 26th. Expect postal delivery of subscription copies in Australia between January 24th and February 10th.

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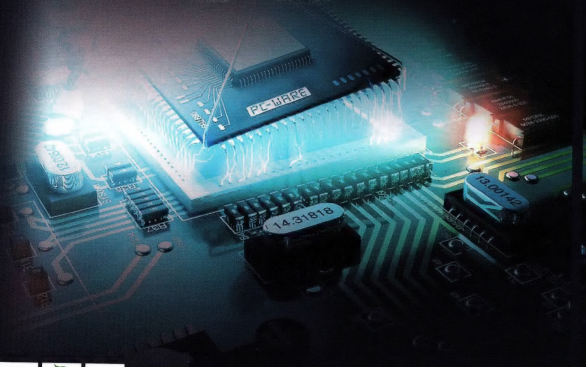

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- Range: 1-13mm
- 0.5mm increments

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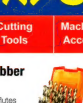
Precision Jobber Drill Set



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- Includes battery

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- Hardened tempered & polished

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- 1 - 13mm
- 1/16 - 1/2"

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- Includes battery

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- 150mm / 6" Vernier
- 100 x 70mm Square

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- Split point
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